VOLUME 61 NUMBER 2

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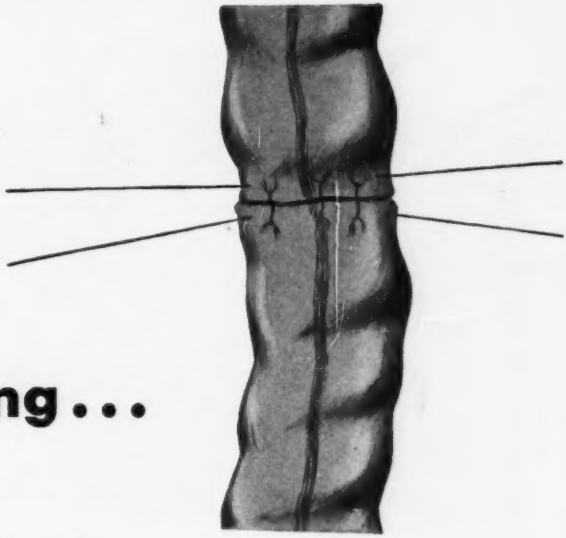

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SURGICAL TREATMENT OF CHRONIC SUPPURATIVE HIDRADENITIS

PAUL W. GREELEY, M.D.
CHICAGO

CHRONIC suppurative hidradenitis (hidrosadenitis suppurativa) is an inflammatory disease that most commonly involves the skin and adjacent subcutaneous tissues of the axillary, inguinal, submammary, perianal and genital regions. This disease in the chronic stage of development is manifested by sinus tracts, abscesses and ulcers. The process affects chiefly the apocrine type of sweat gland, hence the foregoing favorite sites of location. The disease is primarily a dermatologic one, and most of the literature is found among the dermatologic writings. The small percentage of cases that eventually become chronic, with the development of extensive sinus tracts and abscesses, cease to become medical problems, and the treatment advocated in the literature is described curtly, i. e., "plastic surgery." The exact nature of this operation is not explained, and little can be found about it in the surgical literature.

The skin contains two types of sweat glands, the eccrine and apocrine. The eccrine is the commonly distributed ordinary sweat gland. The apocrine is found only in the axillary, submammary, perianal, inguinal and genital locations. It is larger than the eccrine and is located more deeply in the skin. It does not function until the age of puberty and in man may be considered a vestigial remnant. In lower animal forms, however, the apocrine gland is said to work as a scent gland of sexual function.

Inflammation of the axillary glands, or hidradenitis, was first described by Velpeau [1] over one hundred years ago and later by Verneuil.[2]

Read at the Fifty-Seventh Annual Meeting of the Western Surgical Association, Santa Barbara, Calif., Nov. 29, 1949.

From the Department of Surgery, Division of Plastic Surgery, University of Illinois College of Medicine and the University of Illinois Hospitals.

1. Velpeau, A.: Aisselle, in Dictionnaire de médecine, ou répertoire générale des sciences médicales sous le rapport théorique et pratique, ed. 2, Paris, Béchet jeune, 1832-1845, vol. 2, p. 91; Anus, ibid., vol. 3, p. 304; Mammelles, ibid., vol. 19, p. 1.

2. Verneuil, A.: Études sur les tumeurs de la peau at quelques maladies des glandes sudoripares, Arch. gén. de méd. **4**:447 and 693, 1854.

Since that time, several contributions have appeared in the dermatologic literature.[3] It is now well agreed that the disease originates in the apocrine glands. While the clinical appearance is that of a staphylococcic infection, bacteriologic studies do not bear out this theory. It has been the experience of others, as well as our own, that all cultures have shown confusing types of mixed infections. In the chronic cases, however, I have been impressed personally by the tendency of the lesion to spread through either subcutaneous or intracutaneous routes, suggesting clinically that there may be an anaerobic organism that is the chief basic offender. Such a hypothesis has never been proved to my knowledge, but it does warrant careful investigation.

After the development of a discrete abscess, the chronic form of the disease appears in a few cases in spite of good dermatologic therapy. This group will then show a scarred mass of infected lesions that might be described as chronic carbuncles. There are many diffuse intercommunicating sinus tracts, with much scarring, new abscesses and fibrous tissue bands in between. From the many open areas drain large quantities of a putrid, foul-smelling and nauseating type of purulent drainage. When this stage of development has been reached, it becomes obvious that there can be little hope of cure by any type of conservative therapy. It is for this group of cases that plastic surgery has been recommended.

SURGICAL TREATMENT

Surgical treatment should consist of wide excision of all involved areas. When the process has been spread over many parts of the body, it is wiser to remove individual areas at separate operations, the fear being that bacterial emboli might accidentally spill into the blood stream

3. Gans, O.: Histologie der Hautkrankheiten, Berlin, Julius Springer, 1925, vol. 1, p. 360. Macey, H. B.: Axillary Hidrosadenitis Suppurativa: Report of Case, Proc. Staff Meet., Mayo Clin. **16**:758-759 (Nov. 26), 1941. Jackman, R. J., and McQuarrie, H. B.: Hidradenitis Suppurativa: Its Confusion with Pilonidal Disease and Anal Fistula, Am. J. Surg. **77**:349-351 (March) 1949. Lane, J. E.: Hidrosadenitis Axillaris of Verneuil, Arch. Dermat. & Syph. **28**:609 (Nov.) 1933. Brunsting, H. A.: Hidrosadenitis Suppurativa (Abscess of Apocrine Sweat Gland): Preliminary Report, Proc. Staff Meet., Mayo Clin. **12**:753-754 (Dec. 1) 1937. Brunsting, H. A.: Hidradenitis Suppurativa: Study of Clinical and Pathologic Features with Report of 22 Cases and Review of Literature, Arch. Dermat. & Syph. **39**:108-120 (Jan.) 1939. Tachau, P.: Sweat Gland Abscesses in Adults, ibid. **40**:595-600 (Oct.) 1939. Kahn, K.: Plastic Surgery on Axilla, New York State J. Med. **45**:1555-1558 (July 15) 1948. Lauber, H. J.: Beitrag zur Behandlung der Schweissdrüsenabszesse, Münch. med. Wchnschr. **89**:11 (Jan. 2) 1942. Goodall, R. G.: Hidrosadenitis Suppurativa, J. M. A. Alabama **17**:159-163 (Nov.) 1947. Senear, F. E.: Personal communication to the author.

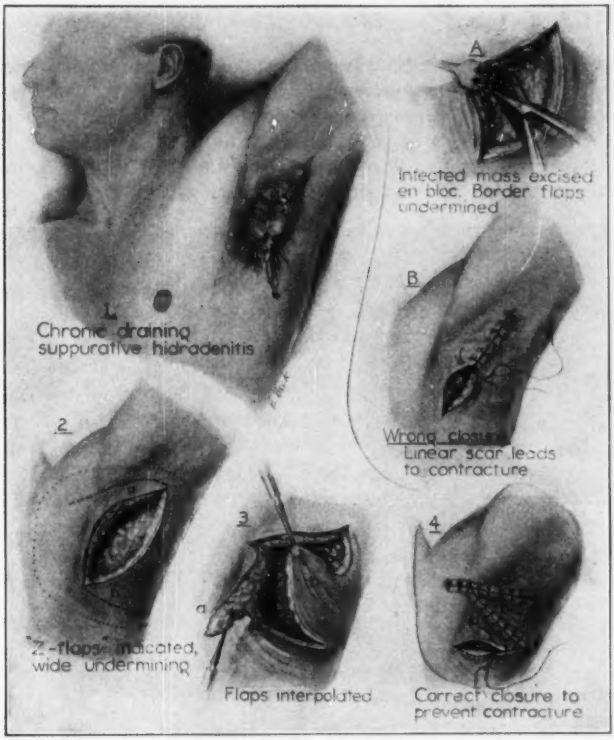

Fig. 1.—Correct method of closure by suture for smaller defects involving the axilla.

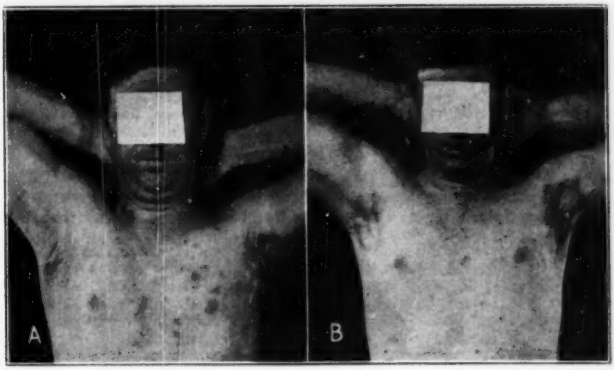

Fig. 2.—*A*, this patient had chronic abscesses of each axilla, most marked on the left side. *B*, healed areas after excision and replacement with split-thickness skin grafts.

and thus precipitate an overwhelming septicemia. The excisions should naturally be carried out under adequate antibiotic therapy, and in many instances blood transfusions must accompany the surgical procedure.

After excision one is confronted with an open wound which must be closed. Selected smaller defects that do not appear grossly to be contaminated may, in conjunction with antibiotic therapy, be closed

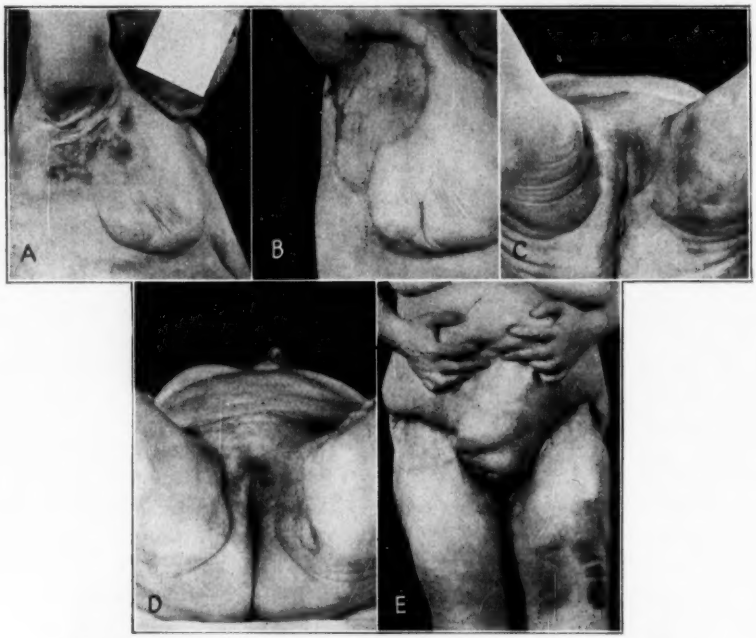

Fig. 3.—In this patient is found all the extreme ramifications of the disease. She presented extensive draining sinus tracts of many years' duration that involved the right axilla, the area beneath each breast, both inguinal areas, the vulva and the inner aspect of each thigh. The left axilla had once been involved but had been cured in its early stage by roentgen therapy. The drainage from the multiplicity of areas was so copious that the patient finally gave up any attempt at dressings and "let the discharge run." She was literally bathed with the drainage at all times and stated that when walking her feet became sore from the "squashing" in her shoes! So terrible was the odor from this stinking mess that she made all those near her feel ill. Because of the wide extent, individual locations were treated separately. The right axilla was excised, permitted to granulate and then covered with a split-thickness skin graft (*B*). The lesions beneath the breasts were removed and the wounds closed by primary suture. After the inguinal areas were excised, that on the left could be closed by suture, but the large defect on the right necessitated a split-thickness skin graft (*E*). The involvement of the perineum and the inner aspects of the thighs was deep and extensive. Consequently, after excision, the defects were permitted to granulate and split-skin grafts applied two weeks later (*C* and *D*).

by some variety of primary suture (fig. 1). Larger defects that appear grossly clean may, according to the surgeon's judgment, be closed at once with a primary split-thickness skin graft. If, however, the excised lesion has been extensive and severely infected, it will be better judgment to dress the wound open. When a firm clean granulating surface has developed during the ensuing ten to fourteen days, the wound should then be closed by the application of a split-thickness skin graft. Surgical treatment of this kind has been routinely successful in this hospital. Dramatic cures may be anticipated in patients who have suffered from chronic draining sinuses that have existed for many years.

SUMMARY

Chronic suppurative hidradenitis is a surgical problem that should be treated by means of wide excision. The resulting cutaneous defect is then closed, either with primary suture or with the application of a split-thickness skin graft, depending on the size and location of the opening.

DISCUSSION

Dr. Eugene A. Osius, Detroit: We had a case similar to the one described by Dr. Greeley, with involvement in the axillas. The interesting feature was that the patient was in a tuberculosis sanitarium. For months the axillary lesions drained, and we were under the impression that they were possibly tuberculous lesions and tried the usual methods, with no result. We finally carried out a radical dissection of all the glands of the axilla, closed by primary suture, as Dr. Greeley suggested, and the patient made an excellent recovery.

Dr. Carleton Mathewson Jr., San Francisco: I am interested in this presentation because we have been confronted with a similar problem in relation to chronic suppuration and multiple draining sinuses which occur about the buttocks and perineum secondary to chronic suppuration in a pilonidal cyst, rectal fistula or posterior urethral fistula. Often the entire buttocks and perineum will become honeycombed with sinuses which do not respond to incision and drainage even after colostomy or cystostomy has been performed to prevent recontamination. We have 2 patients under treatment at present. We have elected to amputate the buttocks on each of these patients, hoping to remove all the infected area. I should like to ask Dr. Greeley if he has ever treated such a patient by amputation of the buttocks and, if he has, what type of graft he uses to cover the defect.

Dr. Greeley, Chicago: Dr. Osius mentioned that these lesions might be related to tuberculosis. We had suspected that too in some of the earlier cases with which we had to deal, and, as a matter of fact, we tried to find the identity of the organism by direct smears, injection into guinea pigs and other customary methods of diagnostic procedure, all of which gave negative results. Then, when streptomycin became available, we tried giving a therapeutic test by adding large doses of this drug to other antibiotics which we had already been using, but all the tests were routinely unsuccessful.

I think, as I said before, that when intelligent consideration is given to what the pathologic process is in some of the late lesions with multiple extensive sinus tracts and much scarring, irrespective of what medical therapy the organism might respond to, it will probably be decided that cure cannot be effected until all the extensive mass has been removed.

Dr. Mathewson's problem is one with which I have had no experience myself, and I will have to talk this over with him in private to see if we cannot decide on some procedure. In general, it would seem to me that if one were to handle these patients by a method similar to that which we have used with paraplegic patients, that is, by excision and closure of the defect by rotation into the surgical wound of a large pedunculated flap to which is attached a good subcutaneous fat pad, an excellent closure would probably be accomplished.

SURGERY OF THE GALLBLADDER

A Study of the Results of Surgical Treatment in Rock County, Wis.

THOMAS J. SNODGRASS, M.D.
WAYNE A. MUNN, M.D.
JANESVILLE, WIS.
AND
THOMAS H. FLARITY, M.D.
BELOIT, WIS.

THE SURGICAL Committee of Rock County Medical Society of Wisconsin in recent years has surveyed and reported results of 8,000 operations for appendicitis [1] and 1,200 operations for various types of hernia [2] and in 1945 reported a series of 756 cases of disease of the gallbladder, including both medical and surgical cases, covering the period from 1929 to 1943.[3] The present survey is a follow-up and includes 329 operations on the biliary tract for the five year period of 1943 to 1948.

Statistics on all phases of the subject have been compiled and studied, but in this presentation only the more important aspects of the study will be discussed. One hundred and fifty-six (47 per cent) of the patients were between the ages of 41 and 60. Two hundred and seventy-six (84 per cent) were women and 53 (16 per cent) were men; the youngest patient was 19 and the oldest 78 years old. Two hundred (60 per cent) of the patients had symptoms from six months to five years, with pain, nausea, colic, localized tenderness and intolerance to foods (86 per cent complained of the last symptom) being the most frequent. Jaundice was present in 14 per cent of the cases. Only 55 per cent of the records included roentgenologic studies, but this figure is inaccurate because

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Read at the Fifty-Seventh Annual Meeting of the Western Surgical Association at Santa Barbara, Calif., Dec. 1, 1949.

1. (*a*) Snodgrass, T. J.; Munn, W. A., and Flarity, T.: Thirty-Five Year Survey of Appendicitis in Rock County, Wisconsin M. J. **42**:928-932 (Sept.) 1943; (*b*) Research Project on Appendicitis in Rock County, Wisconsin M. J. **47**:388-394 (April) 1948.

2. Snodgrass, T. J.; Flarity, T., and Munn, W. A.: Survey of Results of Operations for Hernia in Rock County, Wisconsin, Arch. Surg. **56**:596-604 (May) 1948.

3. Flarity, T. H.; Raube, H. A.; Munn, W. A., and Snodgrass, T. J.: Gallbladder Series [Survey in Rock County], Wisconsin M. J. **44**:984-987 (Oct.) 1945.

in one of the cities a large percentage of the examinations are done in the clinics and unfortunately the reports do not appear on the hospital record.

The upper right rectus incision was used in 246 (75 per cent) of the cases and the transverse incision in only 4, primary closure in 36 (11 per cent) and drainage in 290 (88 per cent). In addition to cholecystectomy, appendectomy was performed in 79 (24 per cent) of the cases. Pelvic operations were added frequently, also herniorrhaphies, trachelorrhaphies, repair of rectoceles and cystoceles, in 1 case a nephrectomy and in another ventral herniorrhaphy plus lipectomy and perineorrhaphy. Biopsy of the liver was obtained in a number of instances.

The pathologic findings are indicated in table 1. It may be noted that in 231 cases (70 per cent) stones were found in the gallbladder.

TABLE 1.—*Pathologic Findings*

Gallbladder with stones	231	70%
Chronic inflamed gallbladder	67	20%
Stones in gallbladder and common duct	10	3%
Gangrenous gallbladder	1	....
Adenocarcinoma of gallbladder	5	2%
Ruptured gallbladder	2	1%
Ptosed gallbladder	0	....
Empyema of gallbladder	2	1%
Gallbladder with adhesions	38	12%
Acute cholecystitis	1	....
Normal gallbladder	23	7%
Hydrops of gallbladder	2	1%
Appendical abscess	2	1%
Mild hepatitis	1	....
Papilloma	2	1%
Fibroma	1	....

There were only two ruptured gallbladders, while in the former series there were ten. Five cases of adenocarcinoma of the gallbladder are recorded, or an incidence of less than 2 per cent. In the first survey [3] only two normal gallbladders were reported by the pathologist in a series of a little over 562 operations, while in this series twenty-three (7 per cent) normal gallbladders were removed, all in one hospital. The term "gallbladder with adhesions" used frequently in the other hospital may include some normal gallbladders. Nine of the normal gallbladders were in one physician's series, 6 patients had no roentgen examination, in 1 there was nonvisualization and in 2 there was a poorly functioning gallbladder. In one series there was nonvisualization or a poorly functioning gallbladder in 3 cases, and in another 2 patients had no roentgen examination. There were 9 patients, each operated on by a different physician, 2 of whom had no roentgen study, 2 showed normally functioning gallbladders with no evidence of stones and 5 showed poorly functioning

gallbladders or some abnormality in the roentgenogram. In comparative studies with other institutions, the Lahey Clinic series [4] reported 1,036 cases, with normal gallbladders in only 6 instances.

Complications following operation on the gallbladder were respiratory conditions in 90 cases (24 per cent), jaundice in 33 (10 per cent), distention in 31 (10 per cent), shock in 13 (4 per cent), cardiac disease in 11 (3 per cent), carcinoma in 7 (2 per cent), pulmonary embolism in 1 and appendical abscess in 2. The large number showing jaundice as a postoperative complication may have some significance in the late results.

The mortality rate of disease of the gallbladder for the State of Wisconsin in the five year period under consideration was 6.9 per hundred thousand. There were 29 deaths in Rock County, a rate of 6.9 per hundred thousand. Of these 29 deaths, 16 are accounted for in this survey as surgical, a mortality rate of 4.8 per cent for the five year period. In the 1929 to 1943 series,[3] of 756 cases studied 562 were surgical, with 44 deaths, or a mortality rate of 5.8 per cent. In the total of the two series, there were 891 surgical cases from 1929 to 1948, with 60 deaths, or an over-all mortality rate of 6.7 per cent. There were 76 women, with 9 (3.5 per cent) deaths and 53 men, with 7 (13.2 per cent) deaths. Again, in a comparative study, the Lahey Clinic series [4] shows 10 deaths in 1,104 cases, or 0.9 per cent. Sanders of Memphis [5] reported a mortality rate of 3.1 per cent in 477 cases in which cholecystectomy alone was the operation performed. Douglass and Lounsbury of Passavant Hospital [6] showed a mortality rate of 5 per cent, or 36 deaths in 724 cases. In the latter study thirty surgeons performed the operations and the series included deaths from carcinoma of the gallbladder, as is the case in the Rock County survey, covering operations performed by forty physicians. This is of importance because in the community under discussion comparatively few of the physicians confine their work exclusively to surgery or could be classed as surgeons. The majority are general practitioners who perform their own operations, and it is noteworthy that in the large metropolitan hospitals the mortality rate may equal or even exceed that of this study, which covers what might be considered a rural area. Only in the highly organized private clinics and in individual series can this mortality be lowered materially.

4. Adams, R., and Stranahan, A.: Cholecystitis and Cholelithiasis: An Analytical Report of 1,104 Operative Cases, Surg., Gynec. & Obst. **85**:776-784 (Dec.) 1947.

5. Sanders, R. L.: Surgical Indications in Diseases of Common Bile Duct, Ann. Surg. **119**:384-390 (March) 1944.

6. Douglass, T. C., and Lounsbury, B. F.: Biliary Tract Surgery in Passavant Memorial Hospital, Quart. Bull. Northwestern Univ. M. School, **22**:21-26, 1948.

In a detailed study of the deaths, postoperative shock and cardiac failure were given as the cause in 6 cases, carcinoma of the head of the pancreas with metastasis in 1, peritonitis in 1, carcinomatosis in 2, pneumonia in 2, bronchopneumonia and pulmonary thrombosis in 1, pulmonary embolism in 1 and mediastinal emphysema with bilateral pneumothorax in 1. In a consideration of the deaths by age, 2 patients were in the forties, 3 in the fifties, 9 in the sixties and 2 in the seventies. There were 113 patients under 40 years of age, with no deaths. There were 156 in the 40 to 60 group, with 5 deaths, or a mortality rate of 3 per cent, and in the 60 to 80 group there were 57, with 11 deaths, or a mortality of 19 per cent. In the Douglass and Lounsbury series,[6] 25 per cent of all the deaths occurred in patients between about 65 and 79 years of age, while in our series over half the deaths occurred in this

TABLE 2.—*Cause of Death and Mortality Rate*

Cause of death			
Postoperative shock and cardiac failure	6	2%	
Carcinoma of head of pancreas with metastasis	1	...	
Peritonitis	1	...	
Carcinomatosis	2	1%	
Pneumonia	3	1%	
Bronchopneumonia and pulmonary thrombosis	1	...	
Pulmonary embolism	1	...	
Mediastinal emphysema with bilateral pneumothorax	1	...	
Mortality rate—16 deaths (4.8%)			
Women (276)	9		(3.3%)
Men (53)	7		(13.2%)
40-60 age group (156 cases)	5	3%	
60-80 age group (57 cases)	11	19%	

age group. Further study showed that 4 of the deaths were from cancer. None of them were surgical deaths, but the patients died in the hospital, 1 in sixteen days, 1 in thirty days, 1 in sixty-six days and 1 in four and a half months. There were 5 deaths within three days of the operation, one patient who died was a 62 year old woman who had undergone a cholecystectomy, suture of an incisional hernia, lipectomy and perineorrhaphy all at one time, and another was a 50 year old man with a high leukocyte count, low temperature and distention in whom exploration had revealed pancreatic necrosis the preceding day. In the first instance the operation was too extensive and the death was avoidable; in the second the death was unavoidable but surgical intervention was probably not indicated. One patient died on the day of the operation from mediastinal emphysema and bilateral pneumothorax; this death was avoidable. Another patient died of shock twelve hours after simple cholecystectomy and appendectomy, and the death was considered avoidable. A 68 year old woman was in desperate condition when she entered the hospital.

Exploration revealed a ruptured gallbladder with stones, and she died thirteen hours after operation. The death was unavoidable, but the outcome was doubtless evident before operation was attempted. A 47 year old woman, treated in the hospital for ten days before operation, had no serious complications except a minor cardiac condition. After cholecystectomy and appendectomy there was an increasingly high temperature, with death on the sixth postoperative day. The committee felt that this death was probably avoidable. Four patients died between four and seven days after operation. A 68 year old woman was operated on the day she entered the hospital and died of general peritonitis on the sixth day, probably an avoidable death. A man 61 years of age was in the hospital three days suffering from abdominal distention and myocarditis. After operation distention continued, and on the seventh day he died of pneumonia. Again, this death was probably avoidable. A man of 62 with increasing jaundice and heart disease was prepared for two weeks before operation with vitamin K, protein and blood transfusions. After cholecystectomy and exploration of the common duct, with the removal of stones and drainage, the patient made a good recovery, but a pulmonary complication developed, and he died on the fourth day postoperatively, his twentieth day in the hospital. This death was unavoidable. One patient died of pulmonary embolism on the twelfth day, and the death was considered unavoidable. A man aged 71 was operated on the day he entered the hospital. Chills, a high leukocyte count, shock and distention developed, and he died of pneumonia and heart failure on the ninth day. With proper preparation this might have been avoidable. One patient died twenty-five days after his operation of a bleeding duodenal ulcer. The gallbladder at operation showed some hypertrophy of the mucosa and papillomatous changes, but evidently this was an error in diagnosis, and the death must be considered avoidable. Elimination of the deaths from carcinoma would reduce the mortality rate to 3.6 per cent. There were 4 deaths which the committee felt were definitely avoidable and 4 others which were considered probably avoidable if additional preparation and care had been used or less extensive surgical procedures performed. There was 1 case in which death was unavoidable but operation was not indicated because of the hopeless condition of the patient. It would appear from this study that by avoiding multiple operations, technical errors and errors in diagnosis and by utilizing modern methods of preparation in the bad risk patient and drainage instead of cholecystectomy when indicated, it might be possible to lower the mortality rate to less than 1 per cent. This supposition is not without some experience to back it up. In our survey of appendicitis [1a] in one of the hospitals, the mortality rate from 1929 to 1942 in a series of 2,062 cases was 3.4 per cent; in the second survey,

from 1942 to 1946,[1b] there were 861 cases, with only 4 deaths, or a mortality rate of 0.5 per cent. While the introduction of new drugs had something to do with this decrease in mortality rate, better surgical treatment was an important factor. There were 11 cholecystotomies, with 1 death resulting from carcinoma of the gallbladder, and there were 11 cases of exploration of the common duct (a little over 3 per cent), with 1 death.

Again, a study of comparative statistics shows that in the Lahey Clinic series [4] of 1,036 cases, the common duct was explored in 504 (45 per cent), and stones were found in 186 (16 per cent). Sanders [5] reported that the common duct was opened in 77 (13.4 per cent) of his series of 576 cases and stones were found in 54 (9.3 per cent). Douglass and Lounsbury [6] noted that the common duct was explored in 89 cases of 724, a little over 10 per cent. If these statistics are generally applicable, then in our series common duct stones have been missed in 10 to 15 per cent of the patients operated on.

FOLLOW-UP STUDY

Many articles appear in the literature concerning the postcholecystectomy syndrome and the management of surgical injuries to the common and hepatic ducts, and it was with the hope of obtaining some information on these subjects that the follow-up study was undertaken. It was felt that sufficient information could be obtained from the study of the patients in the last series, and questionnaires were designed to obtain all the necessary information. This part of the project was financed by a grant from the scientific committee of the Wisconsin State Medical Society. The following questionnaire was sent to 304 patients who had been operated on during the period of 1943 to 1948; it was signed by the superintendent of the hospital in which the operation had been performed.

On....., you had an operation on your gallbladder. May we have your help in a study of the results of gallbladder operations by answering the following questions:

Please Underline:

1. Are you: (1) Well (2) Improved (3) No better.
2. Have you had any attacks of: (1) Pain (2) Nausea (3) Vomiting (4) Colic (5) Inability to eat certain foods (6) Jaundice (7) Tenderness.
3. Have you had any operations since your gallbladder operation? (1) Yes (2) No (a) If yes, what operation?
4. Have you suffered any serious illness since your operation (1) Yes (2) No (a) If yes, what illness?
5. Remarks

In question 2 the symptoms most commonly noted to be present before operation were tabulated. The following letter was sent to 44

physicians together with a list of patients who had been referred by them for surgical intervention or on whom they had performed operation.

The Surgical Committee of the Rock County Medical Society is attempting to evaluate results of surgery of the biliary tract for the period of 1943-1948. Enclosed is a list of your patients who have had surgical treatment. Please note those you consider well, improved or unimproved, taking into account subsequent attacks of pain, nausea, vomiting, gallstone colic, fat or food intolerance, jaundice, tenderness, emesis of bile or other symptoms. Please note if any further surgery has been required for relief of symptoms.

Have you any cases in which there is evidence of injury to the common duct or of development of stenosis over a period of time? In your experience, when symptoms do recur after surgery of the biliary tract, do they appear early or late?

The physicians' evaluation was taken into consideration by the committee in judging the results in all cases and was used in cases in which no other information was available. Table 3 represents the tabulation of their replies.

TABLE 3.—*Consolidation of Physicians' Reports*

Improved	215
No better	10
Food intolerance	9
Incisional hernia	4
Surgical injuries	2
Incisional abscess after discharge	1
Foreign body in abdomen	1
Died after operation	2
Died since operation	20

Table 4 is a résumé of the study together with the results as interpreted by the surgical committee. As noted, the original number of cases was 329, all surgical. In this group there were 39 known deaths and 42 patients whom we were unable to contact in any way. There were 248 answers received from the patients, their relatives or from the physicians in answer to the questionnaire. There were 142 (57.3 per cent) who considered themselves well and 87 (35 per cent) who considered themselves improved, a total of 229 (93 per cent) well or improved. This number is entirely logical because in the physicians' evaluation the word "improved" was used in all cases showing satisfactory results, and in many cases the patients who considered themselves improved listed no symptoms of any kind and no subsequent diseases or operations, while others who considered themselves well underlined symptoms such as mild food intolerance or even colic. The question of "well" or "improved" is therefore largely an individual matter. There were 14 (5 per cent) patients who stated that they were no better. There were two surgical injuries listed which necessitated an

operation later, and there were 3 cases of stenosis of the common duct necessitating later operation.

Despite the apparent excellent results obtained in surgery of the gallbladder, the specific answers to questions relating to symptoms show a different result. Thirty-six (14 per cent) of the patients said they had

TABLE 4.—*Résumé of Study*

Number of cases studied	329		
Known dead	39		
Unable to contact	42		
Replies to questionnaires sent to patients and physicians	248		
Well	142	(57.3%)	98%
Improved	87	(35 %)	
No better	14	(5 %)	
Surgical injuries	2		2%
Late stenosis, common duct	3		
Number of questionnaires sent	304		

TABLE 5.—*Symptoms Following Cholecystectomy*

Symptom	Number of Cases	%
Pain	36	14
Nausea	39	15.7
Vomiting	29	11.7
Colic	20	8
Food intolerance	95	38
Incisional hernia	8	3
Tenderness	50	20
Jaundice	4	1.6

TABLE 6.—*Correlation of Results and Pathologic Process*

	Chronic Cholecystitis	Cholelithiasis	Cholesterosis	Normal	Not Reported	Total
Well	51 (36%)	80 (56%)	2	5 (3.5%)	4	142
Improved	35 (41%)	43 (50%)	2	4 (4.6%)	3	87
No better	5 (35%)	5 (35%)	..	4 (29%)	..	14
Food intolerance	33 (36%)	48 (52%)	3	8 (8.7%)	..	...

had some subsequent pain. Thirty-nine (15 per cent) complained of nausea, and 29 (11 per cent) of vomiting; 20 (8 per cent) stated that they had suffered from colic, and 95 (38 per cent) described intolerance to some types of food, the list including spiced meats, raw onions, oranges, fried foods, fatty foods, gravy, whipped cream, popped corn, bacon, tomatoes, orange juice, tomato soup, steak sauce, starchy food, fresh fruit, eggs, cream and rich food. Eighty-six per cent of the patients complained of intolerance to foods before operation. Eight (3 per cent)

had incisional hernias, 50 (20 per cent) complained of tenderness in the region of the gallbladder and 4 (1.6 per cent) stated that they had jaundice. Table 6 lists the pathologic findings under the classification of well, improved or no better.

Among the well patients 92 per cent had definite chronic cholecystitis or cholelithiasis, while only 3.5 per cent had gallbladders classed as normal. Among the improved patients 84 per cent had chronic cholecystitis or cholelithiasis or both and 4.6 per cent had normal gallbladders. Among the patients who were no better 70 per cent had definite disease of the gallbladder but 29 per cent had had normal gallbladders removed. It will be noted that of the group showing intolerance to foods 88 per cent had definite disease and 8.7 per cent had normal gallbladders.

A careful study was made of the history and the surgical and pathologic findings in the group of 5 patients who later required operation on the common duct and/or hepatic ducts. In the first case hemorrhage was encountered during the operation, and in the control of the hemorrhage the common duct was injured and a branch of the hepatic artery was ligated, according to the surgeon's report. Consultation was called early, and at that time it appeared that no serious damage had been done; later jaundice and evidence of stricture developed, and the patient died elsewhere after an attempt to repair the stricture, peritonitis being given as the cause of death. In the second case a later operation was performed for an injury to the common duct; the duct was repaired and a T tube inserted, but the patient relapsed and was operated on elsewhere for stricture. The third patient was operated on elsewhere for stricture four years after cholecystectomy for chronic cholecystitis and cholelithiasis. The patient stated that during that entire four years he had felt no better and had exactly the same symptoms as he had before his operation and that not until the operation for stricture was performed did he obtain relief. It is difficult to say whether there was an injury to the common duct at the time of the operation or whether there was a failure to recognize the presence of a common duct stone or stricture. The fourth patient was operated on elsewhere for stricture three years after removal of a gallbladder with stones, but it was noted on the operative record that the patient had acute pancreatitis at the time of the operation. It was the opinion of the committee that this person had received temporary relief and that the stricture developed later. The fifth case was somewhat similar, with operation elsewhere for stricture and common duct stone two years and ten months after the removal of a gangrenous gallbladder with stones. The physician noted escape of a good deal of bile-stained fluid from the peritoneal cavity as the abdomen was opened. He also noted that the operation was difficult and that there was evidence of peritonitis. This patient was one of those unfortunate persons who, after operation for stones and stricture of the common

duct, required further surgical intervention for peptic ulcer a year later and in whom peritonitis developed. He was treated with streptomycin, and he complained that "it deadened the cells in the back of my head and now I can't walk very well." There was one primary operation for chronic cholecystitis and stricture of the common duct, probably a congenital anomaly.

A special study was made of the patients who had received no benefit from their operations. They stated that they were not well. As already noted, 4 of this group had normal gallbladders removed and they continued with about the same symptoms they had before. Three in this group of 14 had incisional hernias which gave them great distress, and 1 had thrombophlebitis which persisted for five months. Another patient required an operation for hernia eight months after the operation on his gallbladder, and his wife stated: "He eats what he wants, then vomits, takes soda and is not much better than he was before." One patient had undergone many operations in the past ten years; she stated: "I should like to have my gallbladder put back; I am sick all the time." One patient said that he feels perfectly healthy now but not because he had his gallbladder removed, and another complained of pain in the back and gas and of being sick when he eats and sick when he does not eat. There is 1 patient with uncontrollable diabetes in the group, and another who has diabetes stated that she was not cured and had changed her physician. One patient underwent bilateral superficial femoral ligation five days after the operation on his gallbladder; he now has an incisional hernia and recently had a "severe attack." It is evident, then, that most of the patients' difficulties are related not to their biliary tract but to some other factor which was either present before the operation and has persisted or is the result of the operation. Time does not permit quotations from the letters of many patients who were extremely enthusiastic about the results of the operations and the care they received from their physicians and in the hospitals. As stated before, a few of the most appreciative underlined some of the symptoms indicated on the questionnaire.

Of the 23 who died subsequent to operation (table 7), 1 died of peritonitis in an attempt to repair a stricture, 3 died of cancer of the gallbladder, 1 of cancer of the bile ducts, 4 of cancer elsewhere, and 14 of conditions not related to the biliary system. In the early part of this paper it was noted that only 11 (3 per cent) of the entire group underwent exploration of the common duct in addition to removal of the gallbladder, while in other clinics as high as 10 to 15 per cent of patients had stones in the common duct and in some series 30 to 45 per cent of common ducts were explored at the time of operation. As far as we could find out by this study, in which the common duct was explored, stones removed and the duct drained, the results were excellent, but it must

be a fact that in this series there were many stones in the common duct which were overlooked and which probably account for some of the postoperative symptoms. However, there was no indication that failure to remove a stone from the common duct was the cause of failure of the operation in the patients who were not improved. In the 3 cases of stricture coming on two and three years after cholecystectomy stones in the common duct may have been a factor, but it appears from the findings that peritonitis with localized inflammation present at the time of the operation was the principal cause. A high incidence of exploration of the common duct may be justified in the case of the individual surgeon or specialized group of surgeons, but as a common practice among those who are doing a large percentage of the operations on the gallbladder in this country it would seem to us that it would do more harm than

TABLE 7.—*Cause of Deaths Since Operation*

Carcinoma of gallbladder with metastasis	3
Congestive heart failure	2
Generalized metastatic carcinoma	1
Carcinoma of leg and hip	1
Carcinoma of bile ducts	1
Carcinoma of breast	2
Carcinoma of kidney	1
Surgical injury—peritonitis	1
Carcinoma of mediastinal glands	1
Coronary sclerosis	1
Tubal pregnancy with rupture	1
Cerebral hemorrhage	2
Cerebral embolism, thrombosis	1
Unknown (No record in local vital statistics)	5

good and greatly increase the number of injuries to the common duct as well as the mortality rate. Sanders [5] reported a mortality rate of 6.5 per cent in primary operations on the gallbladder with choledochotomy and of only 3.1 per cent in cholecystectomies alone. In the Hooker series [7] at Henry Ford Hospital there were 165 explorations of the common duct in 2,117 cases, with a mortality rate of 9 per cent. It might follow in the general pattern of surgery of the gallbladder that the higher percentage of normal or near normal gallbladders removed the poorer the results and the more definite the indications for cholecystectomy the better the results. Many small stones must pass after cholecystectomy, and their passing probably accounts for some of the symptoms following the operation. There were few answers to the question asked the physicians of whether these symptoms occurred early or late. Those who did answer were of the opinion that patients frequently had trouble

7. Hooker, D. H.: Exploration of Common Bile Duct: Review of 165 Cases, Am. J. Surg. **60**:88-95 (April) 1943.

for a time soon after operation and then later were entirely free from symptoms. In this series one and a half to six years have elapsed since surgical intervention.

SUMMARY

In conclusion, we feel that this study indicates that additional operations add to the mortality and morbidity in surgery of the gallbladder. Careful preparation and evaluation of the patient and in many cases delay in operation will avoid some of the tragic failures. In the old age group, in which the mortality is so high, simple drainage of the gallbladder, with removal of the stones, may be indicated in many cases in which the preoperative condition is unsatisfactory. Study of the end results of the surgical operations is extremely valuable and instructive, and the best information can be obtained from the patient by a carefully worded questionnaire signed by a third party. The committee feels that surveys on a countywide basis give a more accurate account of the results of surgical operations, the mortality and the morbidity than can be obtained from a selected group of patients operated on by one surgeon or one group of surgeons, for it is in the vast number of small hospitals not connected with educational institutions that the great mass of surgery in this country is performed.

ROLE OF TRACHEOTOMY IN THE POSTOPERATIVE CARE OF PATIENTS SUBJECTED TO ESOPHAGECTOMY

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REMOVAL of the thoracic portion of the esophagus requires a long, tedious and shocking operation. In the postoperative period patients on whom this operation is performed are likely to have considerable pain and are subject to the many hazards of the operation as well as to other hazards which are concomitant and directly related thereto. These include especially pulmonary emboli and atelectasis. All complications which develop in these patients are likely to be particularly severe because of the poor nutritional condition in which they almost invariably present themselves.

For many reasons, pulmonary complications are particularly prone to develop and the patients are likely to have considerable difficulty in raising mucus, which seems to accumulate in especially large amounts in the tracheobronchial tree after esophagectomy. Experience indicates that the higher the level at which the esophagus is dissected, the larger is the amount of mucus that is likely to be present. At the same time the difficulty in keeping the tracheobronchial tree free of this mucus also tends to be great. Difficult to treat or to prevent, the accumulation of mucus alone has been the cause of many fatalities. A variable amount of atelectasis, sometimes localized in one lobe but often diffuse, takes place. If the mucus can be evacuated and the atelectasis relieved within a few hours, little harm results. However, if mucus continues to

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reaccumulate after its removal, as it seems prone to do, the complication becomes serious. Pneumonia may become superimposed on atelectasis and may be the primary cause of death. It is the aim of this paper to present our experience with 11 representative cases in which this problem was paramount. While these cases as presented did follow each other, they do not present the total number in which esophagectomy was performed. They were chosen because they illustrated the particular problem which we faced, and they reflect our thinking in attempting to solve it. Of the 11 patients here reported on, 6 underwent tracheotomy, of whom 1 died and 5 recovered, and 5 were not subjected to this operation, of whom 4 died and 1 recovered.

While many patients are able to expectorate the mucus from their tracheobronchial tree, 4 patients died as a result of not expectorating. This failure sometimes seemed due to inability to cough because of weakness; at other times apparently there was either inadequate stimulus to cough or absence of cough reflex. In some cases the mucus seemed to form so rapidly that the patient did not have sufficient strength to continue coughing. This was especially likely to occur in patients who required high dissection of the esophagus above the aortic arch. Dr. William H. Cassels (recently professor of anesthesiology at the University of Illinois, now at the Mills Memorial Hospital, San Mateo, Calif.), after seeing one of these patients, suggested that a tracheotomy might provide the best means whereby the tracheobronchial tree could be aspirated as often as necessary. By keeping the airway clear in this manner, he felt that we could prevent development of atelectasis, since the mucus (which would ordinarily have to be coughed up) could then be aspirated with a catheter through the tracheotomy tube. Since this suggestion, tracheotomy has been used in 6 cases in which it seemed indicated.

MUCUS AS A POSTOPERATIVE COMPLICATION

The importance of pulmonary complications after any surgical procedure is well known. Formerly accumulation of mucus was often overlooked after an operation until definite pneumonia was present.

The importance of proper evacuation of mucus is reflected by the many steps which have been designed to prevent its accumulation. The cooperation of the patient is tremendously important. This may be secured by talking to the patient preoperatively, explaining to him the importance of trying to cough up any material which may or may not produce a cough reflex. Thorough tracheobronchopharyngeal toilet at the conclusion of the operation is obligatory. Frequent turning of the patient from side to side and hyperventilation, secured by the patient's effort alone aided by the use of carbon dioxide inhalation at half hourly or hourly intervals (during the first two days), have become almost a

routine. Continued prophylactic stir-up is essential because of the tendency of this mucus to reform. The use of drugs which depress the respiratory center (codeine and morphine) would appear to be contraindicated, yet postoperative incisional pain often is so great that free coughing and adequate expectoration of mucus are all but impossible. This is particularly true after operations on the thoracic and upper abdominal areas. With proper splinting of the surgical dressings, the use of sufficient morphine to quiet the pain (yet not in doses sufficient to abolish the cough reflex) may allow the patient to cough in a satisfactory and productive manner.[1] The addition of ethyl alcohol to 1 or 2 liters of the fluids given intravenously (in a 5 per cent solution) may also lessen the amount of opiate required.

Cameron Haight[2] has particularly emphasized the importance of deliberate and repeated use of the tracheal catheter which is passed transnasally when patients are able to cooperate. The introduction of the catheter into the trachea stimulates such violent cough that the mucus is brought to the level at which suction can remove it. He has been able, as have others, to keep the trachea and bronchus dry with repeated aspirations over this route. Such a regimen requires almost the full time services of an especially trained member of the house staff or of a nurse.[3] At times the aspiration is difficult to accomplish or to repeat as often as required. In such cases bronchoscopy may seem to be neccessary. This, however, requires much more personnel, is difficult to repeat frequently and may be exhausting to the patient. The local anesthesia which is used tends to allow even more rapid accumulation of mucus after the bronchoscopy, and the procedure itself is not without danger.

Death is likely to occur if mucus is allowed to accumulate in the tracheobronchial tree. When patients are either unable or unwilling to cough it up and when direct aspiration by means of a catheter fails, tracheotomy may be necessary. This step is not as radical as it may seem and is used in association with many other conditions. In fact, in recent years the institution of tracheotomy as a temporary means of providing either an airway or a means of aspirating mucus has become com-

1. Maier, H. C.: Preoperative, Operative and Postoperative Care in Esophageal Resections, in Pack, G.-T.: Cancer of the Esophagus and Gastric Cardia, St. Louis, C. V. Mosby Company, 1949, p. 26. Blalock, A.: Principles of Surgical Care, Shock and Other Problems, St. Louis, C. V. Mosby Company, 1940, p. 262.

2. Haight, C.: Intratracheal Suction in the Management of Postoperative Pulmonary Complications, Ann. Surg. **107**:218, 1938. Haight, C., and Ransom, H. K.: Observations on the Prevention and Treatment of Postoperative Atelectasis and Bronchopneumonia, Ann. Surg. **114**:243, 1941. Haight, C.: Intratracheal Suction in the Management of Postoperative Pulmonary Complications, Surgery **6**:445, 1939.

3. Curreri, A. J.: Personal communication to the authors.

mon. It is used frequently in cases of skull fracture [4] and of poliomyelitis of the bulbar type [5] as well as in acute laryngotracheal bronchitis.[6] It has been considered essential after radical resection of the jaw,[7] and its use in the grave emergencies associated with respiratory difficulty in tetanus has recently been reemphasized.[8]

Tracheotomy, by tradition, has been considered a serious operation. Actually it is a simple procedure, and, if necessary, it can be done at the conclusion of the operation. The tracheotomy incision can be made and the tube inserted into the trachea as the endotracheal tube is withdrawn. Recent experiences with this procedure emphasize that the simplicity of its execution and the benefit derived outweigh any existing prejudice against it. Once the tracheotomy tube is in place, a catheter may be used to evacuate the mucus as often as is necessary without requiring the cooperation of the patient.

In cases in which the formation of mucus is so rapid after esophagectomy that repeated bronchoscopic procedures every few hours would be necessary to remove it, bronchoscopy is too exhausting to the patient. Tracheotomy gives direct access to the tracheobronchial tree, permitting adequate aspiration whenever necessary. When the tube is tilted to one side or the other, the catheter can be accurately directed into either bronchus to permit direct bronchial aspiration.

There are many factors which predispose toward the presence of respiratory difficulty. The patients are often of an advanced age, they frequently have varying amounts of emphysema and pulmonary fibrosis and some of them have a mild degree of chronic bronchitis with cough. It is of particular importance that any residual mucus in the chest be actively expectorated before the operation. At the time of operation, irritation of the tracheobronchial tree is aggravated by an endotracheal tube and by the anesthetic gases. The operation is a long one, during which one lung (sometimes both) is collapsed for a long period. The higher the resection of the esophagus, the more the vagus nerve is manipulated. This is almost inevitable, and frequently, as in case 10, there is considerable trauma to the trachea in its separation from the esophagus.

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4. Carter, B. N.: Personal communication to the authors.

5. Galloway, T. C.: Management of Respiratory Complications of Poliomyelitis, Arch. Otolaryng. **46**:125 (Aug.) 1947.

6. Brennemann, J.; Clifton, W. M.; Frank, A., and Holinger, P.: Acute Laryngotracheobronchitis, Am. J. Dis. Child. **55**:667-693 (April) 1938. Holinger, P. H., and Andrews, A. H., Jr.: Laryngotracheobronchitis, Southwestern Med. **22**:174-178, 1938.

7. Slaughter, D. P.: Excision of the Jaw for Neoplastic Disease: Indications and Techniques, read before the Tenth Annual Meeting of the Society of University Surgeons, San Francisco, March 26, 1949.

8. Turner, V. C., and Galloway, T. C.: Tetanus Treated as a Respiratory Problem, Arch. Surg. **58**:478 (April) 1949. Spaeth, R.: Tetanus, in Tice, F.: Practice of Medicine, Hagerstown, Md., W. F. Prior Company, 1924, vol. 5.

The fluid which these patients produce may have many sources. If a high degree of obstruction is present, secretions and/or ingested liquids may actually spill over from the esophagus into the trachea. The usual mucus, however, is that typical of the response of the tracheobronchial tree to anesthesia or endotracheal tubes. When a large amount of mucus is secreted, its retention seems to encourage the flow of even more mucus. Preexisting mild bronchitis may easily flare up into acute suppurative bronchitis if excess secretions are not removed.

Occasionally the fluid is that associated with pulmonary edema. There may be a temporary cardiac decompensation, which may be precipitated if an excess of fluids has been given intravenously at the time of operation or immediately thereafter—a time when fluid requirements and replacements are difficult to assess accurately. Such a situation occurred in case 10 as well as in case 6. In case 6, because of the cardiac condition, the use of atropine was indicated. Such therapy would have been considered extremely hazardous without the tracheotomy because of the tendency of the atropine to thicken tracheal mucus. In this case, with the tracheotomy tube in place, small amounts of sodium chloride solution could be introduced through it to help keep the mucus liquid enough to be aspirated and thus to compensate for the drying effect of the atropine.

Each of the approaches to the problem of adequate expectoration mentioned is of undoubted value. The proper cooperation of the patient, proper restraint in the use of sedative drugs, continued stir-up regimen with the use of hyperventilation, encouragement to cough and early ambulation in most cases are sufficient to prevent this phenomenon. When they fail, the active use of tracheal aspiration by means of a nasal (or oral) catheter often suffices. Repeated bronchoscopies, while effective, are exhausting to the patient and almost impossible to perform as frequently as may often be necessary. Tracheotomy solves the problem in such instances.

CASE HISTORIES

The following case histories are illustrative.

CASE 1.—M. L. (St.L. 64006), an obese white woman aged 61, entered St. Luke's Hospital April 8, 1945. A previous diagnosis of a squamous cell carcinoma arising at the cardioesophageal junction was corroborated. On April 18 a typical Sweet [9] operation was done below the aortic arch. At this time the tumor was noted to be small and had not extended to the serosa, and it was the clinical impression that a total cure should have been obtainable. No tumor cells were found in the lymph nodes. At the end of five hours of operating, the patient left the table with a pulse rate of 80, after having received 1,000 cc. of whole blood and 1,000 cc.

9. Sweet, R. H.: Carcinoma of the Superior Mediastinal Segment of the Esophagus: a Technic for Resection and Restoration of the Alimentary Canal, to be published.

of 5 per cent dextrose solution. The postoperative course (fig. 1) was troublesome in only one regard, namely, symptoms and signs secondary to her inability to expectorate mucus; yet this difficulty resulted in her death. Oxygen was given continuously postoperatively, and the patient was also given carbon dioxide for thirty seconds every thirty minutes in an effort to get her to raise and expectorate the mucus. The morning after operation she appeared to be in good condition, but by noon her pulse rate was 120 and her temperature 102 F. and there were many coarse rhonchi audible in the trachea. Repeated intratracheal aspiration was done, and as much as 20 cc. of pink-tinged mucopurulent material was frequently obtained. Her trachea was aspirated until it was dry, and oxygen was given under pressure for thirty minutes. During the afternoon her temperature and

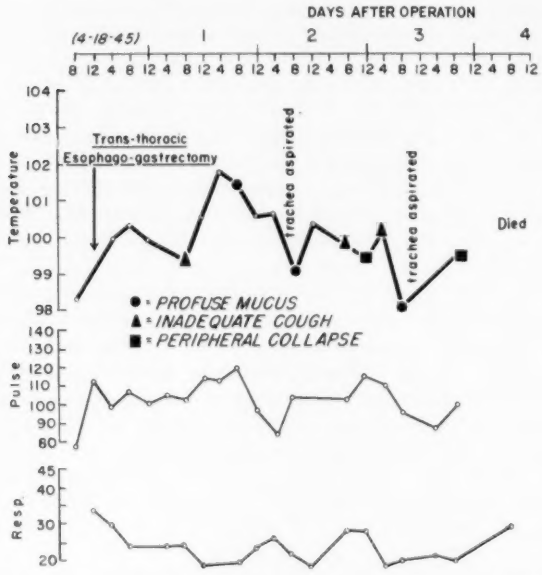

Fig. 1 (case 1).—Note the relatively low pulse and respiratory rates and the lack of temperature elevation which were associated with retention of mucus. The patient was too weak to cough and was helped by direct aspirations. Death was due to bilateral atelectasis. The trachea was aspirated many more times than is indicated on the chart.

pulse rate both rose, and on April 20 (forty-eight hours postoperatively) many fine bubbling rales at the bases of both lungs posteriorly were noted. Later that evening no rales were heard. The patient became irrational on the morning of April 21 (third day postoperatively) and pulled out the Abbott-Rawson tube. Her pulse rate was still 120. At noon 30 cc. of mucopurulent material was again aspirated from the bronchus, and she seemed much improved. On April 22 (fourth postoperative day) at 3 a. m. she again became dyspneic and confused, the pulse rate had increased to 150 and she could not cough; attempts to aspirate the trachea by

catheter failed. The trachea was intubated, and the bronchial tree was aspirated and freed of several large mucus plugs. After this the patient again seemed to be much better, although she was exhausted by the procedure (which she resisted). At 7 a. m. there was reaccumulation of the mucus, and although she was coughing better her pulse rate had increased to 160. She was listless, and at 11:45 a.m. she died.

Autopsy revealed bilateral atelectasis of both lungs as the only significant finding.

Comment.—Large amounts of mucus seemed to form after the first twenty-four hours, and this patient had difficulty in trying to expectorate it. The repeated aspirations of the trachea were successful for only a short time, and after each aspiration the rapid recurrence of mucus made even this inadequate. The patient was short and obese, a fact which probably added to her respiratory embarrassment, and the esophagus had been mobilized almost as high as the level of the aortic arch. It is our feeling at present that a tracheotomy on this patient might have been life saving. It would have allowed us to aspirate her trachea as often as every five minutes, which she needed, whereas the more elaborate procedure of pernasal aspiration required skilled personnel and time to accomplish and could not be done often enough to keep her airway clear.

Case 2.[10]—R. L. (St.L. 96954), a Negro aged 65, entered the hospital on July 7, 1947, with the diagnosis of carcinoma of the lower end of the esophagus, which was corroborated at operation on July 17. At this time a typical Sweet operation was done, the anastomosis being carried out lateral to the aortic arch and between 1½ and 2 inches (3 to 5 cm.) above it. The stomach was anchored to the dome of the pleura to relieve tension. The patient was cooperative in the postoperative period and coughed with vigor, raising profuse amounts of sputum. His pulse rate ranged between 100 and 125 for the first week, after which it gradually dropped. During this time his temperature never rose above 100 F. Beginning about July 29 (twelfth postoperative day) and continuing until August 6 (twentieth postoperative day) his pulse rate began to peak to 120 daily, and during this time the temperature varied between 101.8 and 99 F. All this time he seemed well, was up and around and had a good appetite. During the entire period he received heavy penicillin therapy. He continued to cough up large amounts of mucus with apparent ease.

This course continued until August 12 (twenty-sixth postoperative day), at which time he complained of pain in the left axilla and the left side of the chest, just below the axilla but well above the incision. The possibility that the pain in the chest might be due to pulmonary embolism, coronary thrombosis or postoperative intercostal neuritis was considered. Roentgenograms of the chest were taken periodically but were difficult to interpret. The report on July 29 read: "There is evidence of intermingling radiolucent areas and radiopaque areas with multiple fluid levels; possibly the median radiolucent area extending along the left paravertebral area and aortic arch, with inferior horizontal fluid level, represents gas and fluid in the upward retracted stomach. Undoubtedly there are considerable extrapleural effusion and/or pleural effusion and loculated air." The same findings

10. Expense of the care of this patient was met by the Marquette Charitable Organization, through the courtesy of Dr. Edwin R. Ryerson.

were present on August 4, and on August 18 the interpretation of the roentgenogram indicated that there was fluid in the costophrenic sinus of the left pleural cavity and that it had extended out beyond the margins of the stomach. In addition, emphysema in the left side of the thoracic wall was noted at this time. On August 20 swelling of the left arm and the left thoracic wall occurred. There was spontaneous drainage of pus from the original incision in the posterior axillary line, i. e., empyema necessitatis had occurred. On August 21 (thirty-fifth postoperative day) the patient was found dead in bed before surgical drainage had been established.

Autopsy revealed an abscess in the lower lobe of the left lung, empyema in the apical region of the left pleural cavity and atelectasis of the upper lobe of the left lung; large subcutaneous abscesses of the left side of the chest and left axillary fossa with a fistulous channel between the left apical empyema cavity and the subcutaneous abscess of the left axillary fossa were also found. A fistulous channel was present between the pulmonary abscess of the lower lobe of the left lung and the subcutaneous abscess on the left side of the thoracic wall. The edema of the left upper extremity apparently had been caused by the axillary abscess and not by thrombosis of axillary veins.

Comment.—This patient had recovered from the surgical approach to the gastrointestinal tract without difficulty, and an accumulation of mucus had developed, which, however, he seemed to cough up adequately. The resultant atelectasis, multiple lung abscesses, empyema of the chest and finally formation of subcutaneous abscesses were the all too obvious results of underestimating the extent of his tracheal mucus. He had actually received inadequate treatment. It should be remarked in passing that the patient's excellent swallowing ability, coupled with the low fever and his vigorous cough (which always produced large amounts of mucus) made us pay too little attention to his retention of the tracheal mucus. The continued use of penicillin probably helped to hold his temperature down. In view of our later experience, we feel that this patient would have been benefited by a tracheotomy.

CASE 3.[11]—J. H. (U.S.V.A.H. 17907), white man aged 70, was operated on on July 24, 1947, for stricture of the esophagus thought to be benign. At the time of operation a carcinoma of the middle third of the esophagus was found and a typical Sweet operation done, the anastomosis being carried out anterior to and above the level of the arch of the aorta. The patient coughed poorly after the first twenty-four hours. Tracheal aspirations were unsuccessful in maintaining a dry airway. His temperature rose to 106 F. at the end of forty-eight hours, and he died on July 28, three and a half days after operation. At postmortem examination the following significant findings were noted: (1) carcinoma of the esophagus, with metastasis to the mediastinal lymph nodes; (2) gastroesophageal anastomosis with patent stoma; (3) atelectasis of the lower lobes of both lungs, and (4) pleurisy with effusion, bilateral.

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11. Veterans Administration Hospital, Dwight, Ill. Sponsored by the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions published by the authors are a result of their own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

Comment.—This patient not only expectorated little mucus but was reluctant to cough. Such a patient is particularly well suited to the benefits which can be obtained from a tracheotomy. A catheter, inserted through the tracheotomy tube, might well have stimulated him to breathe and cough adequately. At the same time the secretion could have been aspirated through the tube.

Case 4.—C. B. (R. & E. 336-663), a white man aged 67, was admitted to the Illinois Research Hospital on Jan. 26, 1948, for confirmed carcinoma in the middle

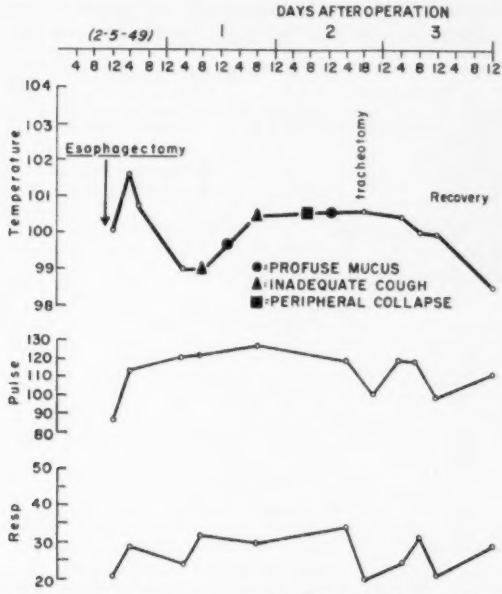

Fig. 2 (case 4).—Note the appearance of peripheral collapse which preceded the execution of the tracheotomy. Several ounces of mucopurulent material were aspirated from the trachea as soon as it was opened. Recovery was rapid after this. Note how the changes in temperature, pulse and respiration belie the true seriousness of the patient's condition, as they did in case 1.

third of the esophagus. On February 5 Dr. C. B. Puestow performed a Sweet operation, the anastomosis being done just below the arch of the aorta. He did well the first day after operation, but by the morning of February 6 (twenty-four hours postoperatively) the pulse rate was 130, respirations were between 30 and 35 and he was cyanotic and obviously had large amounts of mucus in the tracheobronchial tree (fig. 2). Tracheal aspiration was by no means successful in maintaining a dry airway. At this time bronchoscopy was carried out and a large amount of white mucopurulent secretion removed. Although he benefited from this procedure (his pulse rate dropped to 100) he was

markedly fatigued by it. By midafternoon his pulse rate had again risen to 120, and at this time a tracheotomy was done by Dr. A. H. Andrews Jr. At the time of tracheotomy, between 1 and 1½ ounces (30 to 45 cc.) of mucopurulent secretion was aspirated and the patient's improvement was immediately apparent. His pulse rate dropped to around 80 to 90 and his respiratory rate centered around 20. He seemed well after this, was up and about and had no more respiratory difficulty. He died suddenly on February 16 (twelve days postoperatively). Autopsy revealed that death was due to coronary occlusion with recent thrombosis superimposed on an underlying arteriosclerotic plaque on the coronary artery. The trachea and lungs were in good condition.

Comment.—This patient's clinical appearance before the tracheotomy was done left little doubt that he would die if a clear airway was not

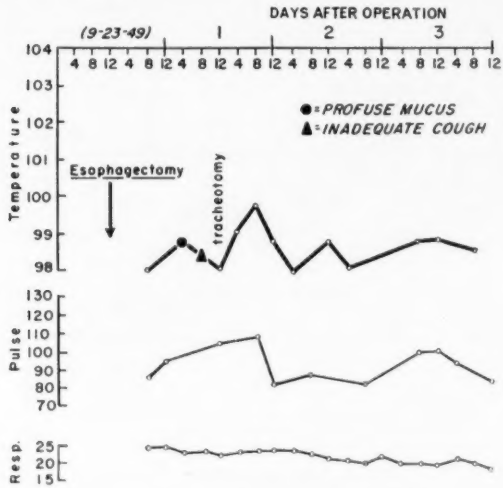

Fig. 3 (case 5).—In this case a tracheotomy was done before an increase of the temperature, pulse and respirations occurred. The indication for it consisted of the large amount of mucus which produced audible rhonchi and which reformed as soon as other mucus was removed. The patient was unable to cough up this material. Recovery followed tracheotomy.

established and maintained. The cyanosis, sounds of bubbling rhonchi in the trachea, elevated temperature, rapid pulse rate and respirations all supported this contention, as did his immediate improvement after bronchoscopy. Tracheotomy was done with ease and little discomfort. It was associated with spectacular and immediate improvement. There was no exhaustion. His sudden unexpected death was only indirectly due to the carcinoma of the esophagus.

Case 5.—F. C. (R. & E. 337-430), a 60 year old white man, was admitted to the hospital on Feb. 9, 1948, for treatment of carcinoma of the middle third of the

esophagus. He was operated on February 23 at which time a typical Sweet operation was performed, anastomosis being done just lateral to and above the arch of the aorta. The presence of distant metastasis made this procedure a palliative one. A definite attempt was made to leave the vagus nerve about the hilus of the lung intact. The stomach was sutured to the roof of the pleura for relief of tension. On February 24 the patient had a normal pulse, temperature and respiratory rate, but there were audible moist rhonchi in the trachea in spite of a vigorous stir-up routine and carbon dioxide inhalations (fig. 3). He was returned to the operating room, and a tracheotomy tube was inserted by Dr. L. Nianick and between 20 and 30 cc. of mucopurulent material obtained. After this there was little difficulty in obtaining mucus by suction, and the patient was up and about by March 1 (seventh postoperative day). The tube was removed on March 8 and the patient was sent home. He was last seen in the outpatient clinic in August 1948, at which time he had signs of recurrence. These progressed until his death, which occurred in October 1948.

Comment.—In this patient we did not use a prophylactic tracheotomy yet did institute one as soon as persistent rhonchi in the trachea indicated voluminous secretions, before clinical signs of mucus retention developed. His temperature, pulse and respirations were normal at the time of operation, but there were audible rhonchi heard throughout the lung fields. These were similar to the ones which C. B. (case 4) had on the day before clinical signs of bronchial obstruction and atelectasis were in evidence.

Case 6.—V. D. (St.L. 109-871), a woman aged 58, entered the hospital March 23, 1948, for the care of previously diagnosed carcinoma of the middle third of the esophagus. She was operated on on March 31 at which time a typical Sweet operation was performed, with anastomosis 1 to 2 inches (2.54 to 5.08 cm.) above and lateral to the arch of the aorta. The vagus nerve was meticulously avoided. Because of our previous experience, a tracheotomy tube was inserted by Dr. A. H. Andrews at the conclusion of the operation. The patient's postoperative course, in spite of this, was punctuated by some difficulty because of the large amount of mucus which was secreted in the tracheobronchial tree. However, this was easily aspirated through the tracheotomy tube. About thirty hours postoperatively her pulse rate was rapid and her respiratory rate irregular. Atropine was given, and she seemed much better. On the morning of the third postoperative day her pulse rate, which had reached a high of 150, rapidly returned to normal. The tracheotomy tube was removed on April 17 (eighteen days postoperatively) and she was dismissed from the hospital on April 23 (twenty-four days postoperatively), just one month after her admission.

Comment.—The prophylactic use of tracheotomy in this patient resulted in a convalescence in which the retention of mucus did not occur, although large amounts were formed. In view of the large amounts of mucus which she did produce, we fear that without the tracheotomy she might not have recovered.

Case 7.—M. S. (St.L. 111-892), a white woman aged 66 entered the hospital on June 21, 1948, for removal of a carcinoma of the middle third of the esophagus. A Sweet operation was carried out on June 25. Again the anastomosis was accomplished with the stomach being brought up anterior to and above the arch

of the aorta. Great care was taken in the prevention of trauma to the branches of the vagus nerve which entered the region of the hilus of the lung. Because of the care observed in preserving the vagus nerve at the time of operation, an attempt was made to avoid the use of tracheotomy, as it was in case 5. However, on June 29 (third postoperative day) the patient was having obvious difficulty expectorating the mucus which she had previously raised with ease. She became cyanotic and was considerably confused. Tracheal aspiration did not relieve the respiratory distress. (In retrospect, we feel that by this time a cerebral vascular accident had developed.) Because of the cyanosis and difficulty in raising the mucus, tracheotomy was done on June 29 by Dr. Kenneth C. Johnston. Improvement was rapid, although there was never complete recovery of her mental acuity. On July 1 she became obviously confused; however, there was no cyanosis. Her temperature was 98.6 F., pulse rate 80 and respiratory rate between 20 and 30. She did not respond well. On July 2 the continuous gastric decompression tube was removed and she was allowed food by mouth. There was little if any mucus to be aspirated from the trachea at this time. She had lost sphincter control on June 29. By July 3, in spite of being able to swallow without difficulty, she was disoriented and weak, had profuse diaphoresis and was irrational. Her death occurred at 9 p. m. on July 3. We were unable to obtain permission for an autopsy in this case, and the cause of death was never satisfactorily explained except that it seemed to be at least in part cerebral.

Comment.—The tracheotomy, which at first had been avoided in this case, was eventually necessary because of the accumulation of mucus. We were worried because we thought we had not done this tracheotomy as early as the patient needed it. The loss of sphincter control and the disorientation which had occurred by the time that tracheotomy became necessary made us feel, in retrospect, that a cerebral accident had developed. We felt that this explained her inability to continue to raise the mucus which she had previously been able to do effectively.

Case 8.—J. H. (R. & E. 351-379), a 74 year old white man, entered the hospital on Jan. 24, 1949, for treatment of esophageal carcinoma which had been proved by previous biopsy. A Sweet operation was done by Dr. C. B. Puestow on January 27, the anastomosis being made about 2 inches (5 cm.) above the level of the arch of the aorta. At the conclusion of the operation the trachea was aspirated by means of bronchoscopy. It was aspirated frequently during the first twenty-four hours. A thoracotomy tube was inserted early on the morning of January 28 because of the continued accumulation of pleural fluid. The patient had great difficulty in raising the mucus. This was aspirated repeatedly by intratracheal catheter, but his hands remained cyanotic and his pulse rate stayed above the level of 110 (fig. 4). The cyanosis and dyspnea increased, and on the morning of January 30 (third postoperative day) he died.

Comment.—Every attempt was made in this case to avoid tracheotomy because of the criticism which we had received that we had been too free with its use. Bronchoscopic aspiration at the conclusion of the operation, carbon dioxide inhalations every hour, early ambulation, tracheal aspiration and bronchoscopy were all performed. The added complication of accumulated pleural fluid made it difficult to assay properly the relative importance of the various factors which might have

contributed to the respiratory difficulty. Autopsy revealed atelectasis of both lungs, and the trachea as well as the bronchi contained a large amount of sanguineous inspissated secretion in the lumen. The right bronchus, particularly, was filled with sanguineous mucoid material.

Case 9.—C. C. (St.L. 126-318), a 61 year old white man, was operated on on Feb. 8, 1949, for carcinoma of the middle third of the esophagus. A Sweet operation was done, anastomosis being lateral to and above the arch of the aorta. Because of the inflammatory reactions about the tumor, both pleural cavities were opened, and

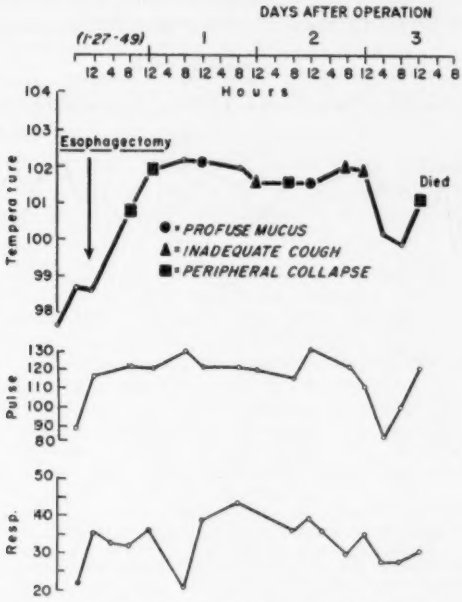

Fig. 4 (case 12).—Signs of peripheral collapse associated with large amounts of tracheal mucus appeared early in this patient and continued until his death, in spite of all measures short of tracheotomy. It is believed that a tracheotomy might have been life saving in this case. Audible rhonchi and peripheral collapse are probably indications of the severity of the retention of mucus in the trachea. The autopsy report was "massive atelectasis of both lungs resulting in death."

bilateral thoracotomy drainage tubes were used postoperatively. Tracheotomy was performed at the conclusion of the operation. There was a profuse amount of mucus and blood aspirated during the first postoperative night. Thereafter appreciable amounts of mucus were obtained frequently and in large quantities. The patient was discouraged during these early days, and we felt that he would not have voluntarily coughed well and might not have raised his rather voluminous secretions. The tracheotomy tube was removed on the tenth postoperative day, and he went home on March 2 (twenty-sixth postoperative day).

Comment.—After the recent experience in case 8, at the conclusion of the operation a tracheotomy was performed, with the knowledge that it was not a requisite. During the first seventy-two hours postoperatively, however, large amounts of mucus were obtained by tracheal catheter. By the end of twenty-four hours the patient had learned to occlude the tracheotomy tube so that he could talk (the inability to talk has caused some of these patients considerable alarm) and the tube was left in place until the tenth postoperative day. Whether or not this tracheotomy was necessary is perhaps a matter of question. However, there is no evidence that it added to the surgical risk. He was periodically

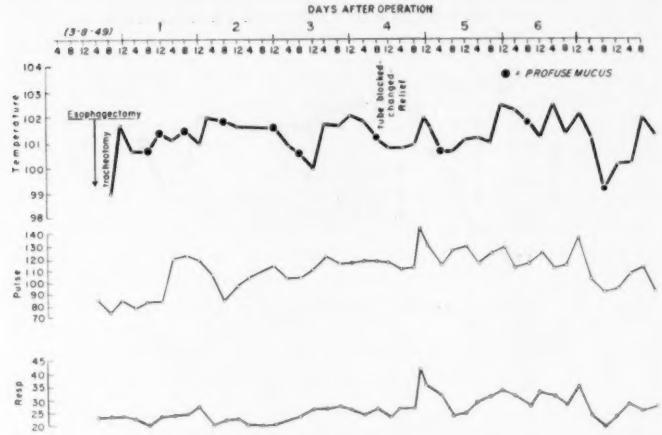

Fig. 5 (case 10).—Tracheotomy instituted at the time of total thoracic esophagectomy gave ready access to the large amount of mucus which was produced in this patient's respiratory tract for many days. The postoperative complications were transient auricular fibrillation and minimal cervical emphysema.

discouraged by his distress and at times not very cooperative. It has been our experience that such patients are less likely to cough.

Case 10.—G. P. (St.L. 127-929), a white man aged 64, entered the hospital on March 5, 1949, because of carcinoma involving the esophagus about 1 inch (2.54 cm.) above the arch of the aorta. A Sweet operation was done in which the fundus of the stomach was pulled up into the neck and the anastomosis done above the clavicle after the thoracic cage had been closed. The operation was tedious because of the tremendous difficulty in freeing the tumor-bearing portion of the esophagus from the trachea and because of diffuse adhesions between the lung and the thoracic wall. At the conclusion of the operation a tracheotomy was done. This was more difficult than usual because the trachea had been displaced to the right by the gastric fundus, which occupied the upper portion of the mediastinum and neck.

About thirty hours postoperatively the patient had a sudden drop in blood pressure to 70 systolic and 50 diastolic, his pulse rate rose to 140 and he had clinical signs of pulmonary edema.

The tracheotomy tube was considered life saving by all who cared for him at this time, i. e., by the resident staff, the interns and us. Since that time he repeatedly had bouts of respiratory difficulty which resulted from the occlusion of the tracheal tube by thick plugs of mucus. The thickness of the mucus in this particular patient (increased by the use of atropine which was necessary to care for the cardiac condition) necessitated the periodic addition of small amounts of sodium chloride solution through the tube to soften the mucus so that it could be aspirated. Evidence of distant metastasis developed several months postoperatively, and the patient died as a result.

Comment.—Tracheotomy was done on this man because we felt certain that with the unusually high resection he could anticipate more difficulty in coughing than would be encountered after a less difficult and less high resection. The repeated bouts of respiratory embarrassment which were readily relieved by suction through the tracheotomy tube convinced all of us associated in his care of the importance of this measure.

Case 11.—F. M. (St.L. 127-427), a man aged 63, was operated on on April 5, 1949, for carcinoma of the lower third of the esophagus. The local lesion was limited, and because there seemed to be reasonable hope of cure a radical resection was done. The entire thoracic esophagus up to about 1 inch (2.5 cm.) above the arch of the aorta was removed and a Sweet operation carried out through the left side of the chest. Because of the technical ease of the operation, it was decided to avoid tracheotomy in his case. Procaine hydrochloride in small quantities was used intravenously throughout the operation. His postoperative course has been free of difficulty from retained mucus, all that formed being satisfactorily aspirated with the transoral or transnasal catheter. The mucus which did form caused trouble only during the second and third postoperative day.

Comment.—Evidence of excessive mucus from the tracheobronchial tree never developed in this case, and hence a tracheotomy was avoided. However, the patient was watched with particular attention to this detail in order not to have its presence pass unnoticed.

COMMENT

The addition of still another operative procedure to the care of patients who must undergo esophagectomy at first may seem unwarranted. Tracheotomy is a simple operation to perform, and we feel that, when done on patients who have needed it, it has not only facilitated care but often saved lives. A tracheotomy tube in place makes direct aspiration of the trachea easy. It may be done by any member of the nursing, resident or intern staff. In this way there is no possibility that the patient's reluctance to cough will be a cause of the retention of mucus. The tracheotomy tube need be only large enough to admit the aspirating

catheter and can be kept closed, allowing the patient to breathe and speak normally except at the time of aspiration.

We have attempted to show by the order in which these patients have been presented the factors which influenced our decision to use or to recommend a tracheotomy in selected cases of postoperative esophagectomy. The unquestioned cause of death in cases 1, 2 and 3 led us to the active discussion of the possibility of the use of tracheotomy. The rapid accumulation of mucus in case 4 shortly after bronchoscopy practically forced us to the recommendation of this operation. The patient's immediate improvement (after the tracheotomy allowed us to aspirate his tracheobronchial tree adequately) left little doubt as to the efficacy as well as the simplicity of this procedure. In case 5 tracheotomy was avoided at first but was instituted at the end of twenty-four hours before cyanosis was apparent yet at a time when the trachea and bronchus were filled with mucus which the patient could not cough up. In case 6 aspiration through a tracheotomy tube was instituted at the conclusion of esophagectomy. During the first four days of the postoperative course, large amounts of mucus were continually aspirated through the tracheotomy tube, and it was not until the fifth day that the amount of mucus so returned seemed to be normal. In this case some of the mucus seemed to be due to a transient pulmonary edema. In case 7, as in case 5, an attempt to avoid tracheotomy was made, yet on the third postoperative day cyanosis made this procedure mandatory. (This particular patient was unable to give continued cooperation because of mental change.)

Again, in case 8, tracheotomy was pointedly avoided, although it seemed to be the most rational procedure. In spite of bronchoscopy and repeated aspirations, autopsy showed that the cause of death was retained mucus.

In case 9, in which tracheotomy was done prophylactically, the postoperative course proceeded smoothly.

In case 10 we elected to do a tracheotomy because of our past experience. It is interesting that the trachea was displaced to the right in the neck by the fundus of the stomach, which had been brought up into the neck. At the end of thirty hours postoperatively, what seemed to be a transient attack of pulmonary edema developed. The removal of the profuse secretion was obviously facilitated by the presence of the tracheotomy tube. Because of the great ease with which the resection was carried out in case 11, coupled with the use of procaine hydrochloride intravenously, as recommended by Taylor,[12] we felt it wise to

12. Taylor, I. B.: Intravenous Use of Procaine During General Anesthesia, read before the Sixth Annual Meeting, Central Surgical Association, Cleveland, February 1949.

attempt to avoid tracheotomy in this case. The smooth postoperative convalescence justified this decision.

Indications for Tracheotomy.—The presence of audible rhonchi in the tracheobronchial tree, indicating voluminous mucus which the patient cannot expectorate and which reforms rapidly after aspiration, is usually a significant early observation. In cases in which tracheotomy may be indicated, dyspnea, rapid respiratory rate, elevated pulse rate and profuse diaphoresis follow. If active cough or tracheal aspiration will completely relieve all these symptoms and will prevent their recurrence, then no further steps need be taken aside from continuation of these routines. We feel that cyanosis should not be allowed to develop as it did in cases 4 and 7, since the cyanosis indicates that excess mucus has already been allowed to accumulate in such cases.

In patients in whom formation of large amounts of mucus occurs rapidly, proper nasotracheobronchial toilet by the transnasal route of Haight often can be maintained only when the house officer remains with them at all times. Few hospitals are so fortunate as to have sufficient help available. Tracheotomy allows a nurse to achieve the same effect. Careful attention to the patient's early symptoms should allow the institution of tracheotomy early enough to prevent serious pulmonary infection and yet give the opportunity of avoiding tracheotomy when it is possible to maintain proper tracheobronchial toilet without it. It is important to make such a decision early, before the secretions trickle so far into the pulmonary parenchyma that atelectasis develops.

The use by Taylor and his associates [12] of procaine intravenously as the anesthetic agent should be mentioned. Their early favorable reports indicate that this agent may be associated with the formation of less mucus if its dangers can be avoided.

Patients who have undergone tracheotomy require constant attention.[5] The simple presence of a tracheotomy tube does not guarantee against its becoming plugged. However, when the tube becomes occluded or when the mucus below it is voluminous and heavy, aspiration at once clears the airway—something which cannot be accomplished with anything like the same ease and certainty in a patient in whom a tracheotomy has not been performed.

SUMMARY AND CONCLUSIONS

While we do not recommend tracheotomy as a routine measure, in our opinion it represents a procedure of considerable advantage. It may be life saving in the care of patients who have undergone excision of the esophagus for carcinoma in the upper and middle portions.

Reports of 11 illustrative cases are presented. In 4, death was definitely due to retained secretion. Of the 6 patients who underwent tracheotomy, none seemed harmed by it. We felt that all were greatly benefited, and all recovered to the point of eating well. One died from an unexplained cause; the second had coronary thrombosis, and the other 4 left the hospital in satisfactory condition. In the one in whom tracheotomy was not performed and who lived no amount of mucus developed at any time in the postoperative course which was not readily handled by the more conventional means of oral and transoral suction.

The advice and help given by Dr. R. W. Keeton, Grant Laing, T. J. Coogan, H. C. Ragsdale, Ralph Dolkart, A. P. Steinberg and C. A. Johnson were of inestimable value in the care of these patients.

COMBINED ABDOMINAL AND RIGHT THORACIC APPROACH TO LESIONS OF THE ESOPHAGUS

CARLETON MATHEWSON Jr., M.D.
AND
ROY COHN, M.D.
SAN FRANCISCO

ALTHOUGH many of the great surgeons of the past century have repeatedly attacked the problem of resection of the esophagus, their limited success has been mainly with transcervical and transabdominal dissections. In 1938 Adams and Phemister [1] reported the first successful transpleural and transdiaphragmatic resection with intrapleural esophagogastric anastomosis. This noteworthy accomplishment seems to have marked the turning point in surgery of the esophagus. Since then a number of surgeons in various clinics throughout the world have reported a series of successful resections with a remarkable fall in the associated morbidity and mortality.

A number of factors, including the preoperative preparation of the patient, improved anesthesiology, chemotherapy and better postoperative care, have contributed to a major degree to this success. Not the least important factor, however, has been the standardization of operative technic. The left transthoracic approach for lesions of the cardia of the stomach and lesions of the lower third of the esophagus is now a recognized standard method.

It is now known that all sections of the esophagus including the lower cervical region can be resected and replaced by transposition of the stomach into the thorax. Most surgeons advocate the left transpleural approach to the esophagus regardless of the level of the lesion. There are outstanding disadvantages, however, to the conventional approaches through the left side of the thorax to lesions occupying the thoracic portion of the esophagus extending from just above the arch of the aorta to a point just below the level of the inferior pulmonary veins, the region usually referred to as the middle third.

From the Stanford University Surgical Service, San Francisco Hospital.

Read at the Fifty-Seventh Annual Meeting of the Western Surgical Association, Santa Barbara, Calif., Dec. 1, 1949.

1. Adams, W. E., and Phemister, D. B.: Carcinoma of the Lower Thoracic Esophagus: Report of a Successful Resection and Esophagogastrostomy, J. Thoracic Surg. **7**:621, 1938.

The purpose of this communication is to relate our experience with the combined abdominal and right transthoracic approach to lesions of the middle third as advocated by Ivor Lewis, of London, England, in 1946 [2] and again by Joseph E. Macmanus, of Buffalo, N. Y., in 1948.[3] Our attention was first directed to the advisability and advantages of this approach when we were called on to resect a lye stricture of the entire thoracic portion of the esophagus in a patient whose left pleural space was completely obliterated by dense adhesions from previous operations. The entire thoracic region of the esophagus was resected by the combined abdominal and right thoracic approach and the stomach successfully anastomosed to the esophagus at the apex of the right pleural cavity. The great ease with which this procedure was accomplished and the benign postoperative course induced us to attempt the same procedure in a series of cases of carcinoma of the middle third of the esophagus, the type of case in which we had often encountered great difficulty resecting the lesion from behind the aorta, using the standard left transthoracic approach. Our experience has been most encouraging.

The difficulties encountered in both the exposure and the resection of lesions of the middle third of the esophagus are well known to surgeons who have approached these lesions from the left side of the thorax. The increased mortality associated with anastomoses above the arch of the aorta as compared to those below the arch is well known. This increase in mortality is incident to the difficulties encountered in dissection in this area rather than to the actual anastomosis itself. As Sweet [4] has mentioned, it is actually often more difficult to accomplish the infra-aortic anastomosis than the supra-aortic one because of the limited space, bounded by the aortic arch above the hilus of the lung anteriorly and the descending aorta posteriorly. In an effort to avoid these difficulties, an inadequate resection of the normal esophagus above the lesion is often accomplished.

With the exception of the azygos vein, which is easily identified and sectioned, there are no obstacles to the exposure, of the esophagus in the right pleural cavity. After transection of the azygos vein and incision of the right mediastinal pleura, the entire esophagus can be dissected free from the apex of the pleural cavity to the crus of the diaphragm. The aortic arch and descending aorta, which create an obstacle in the left side of the chest, become a safety barrier between the surgeon and the left pleural cavity. Lesions found adherent to the aorta or to the trachea

2. Lewis, I.: The Surgical Treatment of Carcinoma of the Esophagus with Special Reference to New Operation for Growths of Middle Third, Brit. J. Surg. **34**:18, 1946.

3. Macmanus, J. E.: Combined Left Abdominal and Right Thoracic Approach to Resection of Esophageal Neoplasms, Surgery **24**:9, 1948.

4. Churchill, E. D., and Sweet, R. H.: Transthoracic Resections of Tumors of the Stomach and Esophagus, Ann. Surg. **115**:897, 1942.

may be dissected free under direct vision, whereas blind blunt dissection is the rule in the left region of the chest even when the upper intercostal vessels are cut and the arch of the aorta reflected. The disastrous results of pulmonary and cardiac reflexes due to trauma in this region are best avoided. The ease of exposure from the right side of the chest tends to prevent trauma and allows ample room for a wide resection of the esophagus above the lesion. Esophagogastric anastomosis can be accomplished without the handicap of the limited space encountered on the left side. Bilateral open pneumothorax can be avoided more easily when the operation is in the right side of the chest, and one need never fear injury to the azygos vein, which is always exposed and usually ligated.

The diaphragm must be opened widely to facilitate exploration of the abdomen and mobilization of the stomach in the left transpleural approach. This stage of the operation is accomplished simply and with a minimum of trauma to vital structures through a midline upper abdominal incision. Although mobilization of the cardia and ligation of the left gastric artery are accomplished more easily through the diaphragm, mobilization of the remainder of the stomach and particularly the vessels at the pylorus is much simpler through an abdominal incision. The quiet diaphragm resulting from its transection is a decided hazard to the patient in the immediate postoperative period. Postoperative atelectasis in the lower lobe of the left lung, with resultant pneumonitis, is a common complication of the transdiaphragmatic procedure. An intact functioning diaphragm postoperatively has been one of the great advantages of the combined procedure.

Carcinoma of the middle thoracic portion of the esophagus is more likely to be fixed to surrounding organs than is the same lesion in the lower third. For this reason, a large number of lesions discovered at this level will be resected as a palliative procedure rather than as an attempted cure. We have been impressed by the great relief afforded patients and agree with others who advocate resection purely as a palliative procedure. The earliest lesion that we have encountered in this part of the esophagus was discovered in a patient with cardiac disease in an attempt to outline the posterior border of the heart after a swallow of barium. The local lesion was a small one confined to the wall of the esophagus and easily resected. The patient died soon after operation from cardiac flutter and was found to have glandular metastasis in the right side of the chest not seen at operation.

We have been able to accomplish palliative resections of fixed carcinomas in the middle third of the esophagus through the right side of the chest with gratifying results; these would most certainly have been considered inoperable had we approached them through the conventional left thoracic incision.

TECHNIC OF OPERATION

Excellent descriptions of the detailed operative procedure are contained in the original reports of Ivor Lewis in the *British Journal of Surgery* for July 1946 and in the report of Joseph E. Macmanus in *Surgery*, July 1948. With one exception, we have carried out the operation in every case at one sitting. We prefer a midline upper abdominal incision because of the ease with which it can be closed. We have not considered irresectable abdominal lymph nodes or metastasis to the liver to be contraindications to the complete resection. After careful ligation of the vessels in the gastrocolic omentum, in which care is taken to preserve the right gastroepiploic artery, the vasa brevia to the spleen are ligated and thus the entire greater curvature is freed. The left gastric artery is ligated as close to its origin as possible. The stomach is then freed on the lesser curvature. The left lobe of the liver may be reflected to the right after section of the suspensory ligament. The lower end of the esophagus is freed by blunt dissection after the peritoneal reflection is cut from the diaphragm. The esophagus is dissected free from the surrounding areolar tissue as high into the chest as possible. This makes subsequent dissection from the chest much simpler and tends to dilate the aperture between the crus of the diaphragm. The abdomen is closed and the patient turned on the left side.

The chest is opened usually in the seventh intercostal space. A rib has been resected in some cases and the pleura opened through its bed. Exploration at this stage will decide the operability of the lesion. It has been our feeling that, if at all possible, the local lesion in the esophagus should be resected even though carcinoma remains in the chest. It is possible by careful sharp dissection to remove a lesion which has actually grown into the aorta or bronchus without irreparable damage to these organs. It is usually necessary at the beginning of the mobilization of the esophagus to ligate and cut the azygos vein. After complete mobilization of the esophageal lesion, the stomach is pulled up through the crus of the diaphragm, care being taken not to turn it on its longitudinal axis. Such a false maneuver may cause obstruction or injury to the blood supply. The anastomosis is carried out by the usual double layer interrupted fine silk technic, and the stomach is fixed in the elevated position with interrupted silk sutures to the mediastinal pleura. If the left crus of the diaphragm has been cut, the stomach should be sutured to the diaphragm to prevent herniation of abdominal viscera into the thoracic cavity. This step we have omitted when the crus was not cut. The chest is then closed in the routine fashion, with underwater drainage.

MATERIAL

We have now carried out the combined abdominal–right transthoracic operation on 7 consecutive patients ranging in age from 40 to 70 years, without a single postoperative death. In all but one the procedure was

completed in one stage. Our first operation was accomplished in two stages ten days apart because a previously performed gastrostomy fistula had to be taken down at the first operation and it was feared that secondary infection might be a hazard if the chest were opened at that time. No untoward difficulties were experienced because of the delay between stages in this particular case.

In 5 patients the right crus of the diaphragm was cut according to the Macmanus [3] modification of the Lewis [2] technic, with subsequent suture of the diaphragm to the transposed stomach. In 2 patients the normal aperture between the crus of the diaphragm was simply dilated and the stomach drawn through this aperture into the thoracic cavity. No attempt was made to suture the stomach to the diaphragm in these cases. This would seem to be the procedure of choice because of minimal trauma to the diaphragm, provided it is apparent at the time of operation that adequate space is secured and no obstruction to the lumen of the stomach after its transposition into the chest is evident.

In 1 of our patients delayed emptying of the stomach became a serious postoperative complication. Roentgenologic examination made it appear that an obstruction had occurred at the diaphragmatic aperture. Subsequent laparotomy proved this not to be the case. The aperture proved to be widely patent. A Levin tube was passed with ease from the esophagus into the duodenum under direct guidance of the surgeon. It is our belief that this patient's difficulties were most likely due to an atonic stomach following vagotomy rather than to actual mechanical obstruction. This is our only experience with such a complication.

As mentioned previously, the first operation was performed to relieve a patient of stricture due to a lye burn. The subsequent procedures were accomplished in patients suffering with carcinoma of the middle third of the esophagus in whom we anticipated difficulties with the conventional left thoracic approach. Unfortunately, in every case of carcinoma it was apparent at operation that a cure could not be expected because of dissemination of the disease beyond complete surgical extirpation. Nevertheless, we were able to complete the operation in every case without a surgical death. The relief afforded these patients seems to have justified the operation, and they have all left the hospital without postoperative complication with the exception of the patient with delayed gastric emptying. His condition is now moderately well controlled with frequent small feedings.

In 3 patients the carcinoma was densely adherent to the arch of the aorta and in 1 to the trachea. In each of these the esophagus was removed by sharp dissection, a portion of the tumor being left behind. It seemed evident that resection through the left side of the chest would have been impossible in these patients.

COMMENT

It might be argued that a combined right thoracoabdominal incision might afford better exposure when this lesion is being approached from the right side. The main objection to this type of incision in our opinion centers about the necessity of transection of the diaphragm. One of the great advantages of the combined approach is the small amount of trauma to the diaphragm, which minimizes the loss of tussive power in the immediate postoperative period. We have experienced no great difficulty with two incisions except the inconvenience of changing position and redraping during the operation. Lewis [2] anticipated that the combined procedure might constitute too great an undertaking in the aged and debilitated patient, and he therefore advocated the performance of the operation in two stages ten to fifteen days apart. We have carried out the entire procedure in a single stage with one exception and have found it less shocking than the one stage left transthoracic operation because of the ease of exposure of the esophagus in the right side of the chest.

It is anticipated that we may in the future encounter patients in whom we will be unable to resect the esophagus after preparation of the stomach for transposition from below. This we do not feel is a serious objection to the procedure and is offset by our belief that more attempts will be abandoned when the approach is through the left side of the chest than when it is through the right.

Macmanus has modified the technic described by Lewis by making a point of dividing the right crus of the diaphragm near its origin. He feels that this division not only makes the blunt dissection from below of the lower 2 inches (5 cm.) of the mediastinum easier but also allows one a larger space through which to maneuver the stomach during the thoracic stage of the operation. He also feels that the diaphragm is less likely to act as a partial obstruction to the vagotomized stomach at some later date. We have utilized both technics and are inclined to believe that the normal aperture is usually of sufficient size to facilitate the original dissection and ordinarily is large enough not to act as a barrier to emptying in the postoperative period. It certainly is an advantage to interfere as little as possible with the normal function of the diaphragm whenever possible. We have encountered postoperative delay in the emptying time of the stomach only once and that was in a patient in whom the crus had been cut.

SUMMARY

The advantages of the combined abdominal and right thoracic approach to lesions of the middle third of the esophagus are discussed and our experience with 7 consecutive patients operated on successfully is related.

PARTIAL ESOPHAGOGASTRECTOMY IN THE TREATMENT OF ESOPHAGOGASTRIC VARICES

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THE INEVITABLE life-taking character of hemorrhage from esophagogastric varices still stands as a challenge. Some success and much failure have attended the numerous attempts that have been made in its management.[1] Present evidence suggests that some forms of portacaval shunt offers substantial palliation to patients with generalized portal hypertension.[2] Undoubtedly the rare patients with distal splenic vein obstruction respond well to simple splenectomy. Most

Dr. Kittle was co-author of this paper by invitation.

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1. Baronofsky, I. D.: Portal Hypertension with Special Reference to the Acid-Peptic Factor in the Causation of Hemorrhage and Extensive Gastric Resection in Its Treatment, Surgery **25**:135-168 (Jan.) 1949. Crafoord, C., and Frenckner, P.: New Surgical Treatment of Varicose Veins of the Esophagus, Acta oto-laryng. **27**:422-429, 1930. Grace, E. J.: Control of Massive Esophageal Hemorrhage Secondary to Liver Damage (Cirrhosis) by Ligation of the Coronary Vein and Injection of Sodium Morrhuate, Ann. Surg. **116**:387-393 (Sept.) 1942. Mayo, W. J.: The Surgical Treatment of Hepatic Cirrhosis, Ann. Surg. **80**:419-424 (Sept.) 1924. Moersch, H. J.: Treatment of Esophageal Varices by Injection of a Sclerosing Solution, J. A. M. A. **135**:754-757 (Nov. 22) 1947. Rowntree, L. G.; Walters, W., and McIndoe, A. H.: End Result of Tying of the Coronary Vein for Prevention of Hemorrhage from Esophageal Varices, Proc. Staff Meet., Mayo Clin. **4**:263-264 (Sept. 4) 1929. Som, M. L., and Garlock, J. H.: New Approach to the Treatment of Esophageal Varices, J. A. M. A. **135**:628-629 (Nov. 8) 1947. Walters, W.; Moersch, H. J., and McKinnon, D. A.: Bleeding Esophageal Varices: An Evaluation of Methods Directed Toward Their Control Especially by Direct Injection of a Sclerosing Solution, Arch. Surg. **41**:1101-1117 (Nov.) 1940.

2. Blakemore, A. H.: Porta-Caval Anastomosis—Observations on Technic and Postoperative Care, S. Clin. North America **28**:279-289 (April) 1948. Blalock, A.: Use of Shunt or By-Pass Operations in Treatment of Certain Circulatory Disorders, Including Portal Hypertension and Pulmonic Stenosis, Ann. Surg. **125**:129-141 (Feb.) 1947. Linton, R. R.: Portacaval Shunts in the Treatment of Portal Hypertension with Special Reference to Patients Previously Operated upon, New England J. Med. **238**:723-727 (May 20) 1948. Whipple, A. O.: Problems of Portal Hypertension in Relation to Hepatosplenopathies, Ann. Surg. **122**:449-475 (Oct.) 1945.

difficult to manage are young persons without evidence of cirrhosis or of generalized portal hypertension who present varices and splenomegaly, many having undergone ineffectual splenectomy. Basic understanding concerning the latter patients has changed little since Professor Banti's original observations made nearly three quarters of a century ago.[3] Why should they early present morphologic evidence suggesting obstruction of only the splenic segment of the portal bed and yet later have definite cirrhosis manifest even by ascites? What effect might be obtained with early radical resection of all obviously diseased parts? With the hope of learning some part of the answer to this question we have recently subjected 5 such patients to esophagogastrectomy as suggested by Phemister and Humphreys.[4]

The following cases have been observed.

Case 1.—C. H., our first patient, was a 7 year old invalid girl with imperforate anus, rectovaginal fistula and megacolon. She first experienced massive hemorrhage of the gastrointestinal tract in June 1945, at the age of 5 years. At this time she repeatedly vomited large quantities of bright red blood and passed voluminous tarry stools for a period of ten days. Three other near fatal episodes of hemorrhage, requiring transfusion therapy, occurred in May 1946, October 1946 and March 1947. At the time of her admission to the Medical Center in June 1947 she presented pallor and extreme distention of the abdomen caused by impacted fecal masses in the colon. A high degree of obstruction was obviously present at the rectovaginal fistula. She was found to have a red blood cell count of 2,690,000 per cubic millimeter, a white blood cell count of 13,200, a hemoglobin content of 8.0 Gm. per hundred cubic centimeters and a platelet count of 170,000. Roentgen examination confirmed the presence of a huge colon filled with feces. Though varices could not be demonstrated at fluoroscopy, on esophagoscopy, several were visualized in the lower third of the esophagus. Neither the spleen nor the liver was palpable. Since from the history it appeared that each bout of hemorrhage had followed a prolonged period of obstipation, it seemed best first to establish a colostomy, with the twofold purpose of relieving increased intra-abdominal tension and allowing preparation of the distal end of the colon and rectum for plastic reconstruction of the perineum. This procedure had the additional advantage of permitting a thorough abdominal exploration of the liver, spleen, gastrointestinal tract and portal vascular system. Just as we had prepared to go ahead with this operation the child suddenly began to hemorrhage. Whole blood transfusions in the amount of 3,200 cc. were required merely to stabilize her blood pressure above shock level. This modified our plan for elective intervention, and instead on Aug. 1, 1947, after bleeding had ceased, her abdomen was opened, with the hope of being able to evaluate more precisely the underlying cause of the varices. The liver and spleen

3. Banti, G.: La splenomegalia con cirrosi del fegato (Splenomegaly with Cirrhosis of the Liver), Sez. Biol. **48**:407-432. Sperimentale and Comun. e Riv. **48**:447-452, 1894; translated, M. Classics **1**:907-912 (June) 1937; Splenomegalie mit Lebercirrhose (Splenomegaly with Cirrhosis of the Liver), Beitr. z. path. Anat. u. z. allg. Path. **24**:21-33, 1898; translated, M. Classics **1**:913-927 (June) 1937.

4. Phemister, D. B., and Humphreys, E. M.: Gastro-Esophageal Resection and Total Gastrectomy in the Treatment of Bleeding Varicose Veins in Banti's Syndrome, Ann. Surg. **126**:397-410 (Oct.) 1947.

were found to be normal, with no evidence of increased portal pressure. She hemorrhaged massively after this operation and required further transfusion therapy. At the family's request she was dismissed from the hospital on August 22, only to be readmitted on October 7 because of another massive hemorrhage, which again required transfusion in order to save her life. When bleeding had stopped, a sigmoid colostomy was established. Postoperatively she experienced prolonged massive hemorrhage. The decision was then reached to carry out a partial esophagogastrectomy and splenectomy to eradicate the bleeding points, which were considered to be localized to the lower portion of the esophagus and upper area of the stomach. On December 4 a transthoracic exploration of the left upper quadrant was carried out. Varicosities were noted about the lower end of the esophagus; so the lower third of the esophagus and the upper third of the stomach were resected together with an apparently normal spleen. Bowel continuity was established by means of an esophagogastrostomy. The patient enjoyed an uneventful course after this operation and was dismissed from the hospital on December 17. During the following year there were three admissions to the hospital, one for evacuation of an impaction, one for reconstruction of the perineal defect and one for dilatation of the artificial anus. Eighteen months after esophagogastrectomy, again at a time of marked obstipation, the child vomited an ounce (30 cc.) of bright blood and was admitted to the Medical Center as an emergency. No further bleeding occurred during a week of hospitalization, so she was discharged home. She experienced repeated hemorrhages during the following weeks and was admitted to another hospital, where she died as the result of hemorrhage in September 1949, twenty-one months after resection.

Case 2.—G. F., a 9 year old boy, was admitted to the Medical Center in May 1948 because of hemorrhage with a history of having first bled when 6 years of age. Similar severe attacks of hematemesis and melena had occurred regularly every three months thereafter. In January 1947, at the age of 7½ years, he had undergone splenectomy, after which he continued to bleed, experiencing massive loss in September 1947, January 1948 and April 1948. Pallor and a poor state of nutrition were the outstanding findings on physical examination. The liver was not palpable. The red blood cell count was 2,800,000, the white blood cell count 11,750 and the hemoglobin content 7.4 Gm. per hundred cubic centimeters. The total plasma protein level and albumin-globulin ratio were normal. He was found to have a negative reaction to the cephalin flocculation test, the thymol turbidity was 3 plus and there was slight impairment of hippuric acid synthesis. Many huge varices were demonstrated in the distal portion of the esophagus at fluoroscopy. We felt that this patient had generalized portal hypertension, for which, on May 18, 1948, we carried out laparotomy to establish a portacaval shunt. However, on exploration of the abdomen, no evidence of portal hypertension was found and the liver appeared essentially normal. Only at the esophagogastric junction were any prominent veins observed, and therefore the idea of a shunt was abandoned. Biopsy of the liver was carried out, and it was found to be normal microscopically except for the presence of a slight inflammatory cell infiltration in the interlobular connective tissue. The patient enjoyed an uneventful postoperative course and was discharged on the eleventh postoperative day. One month later exsanguination nearly occurred. He was rushed to his local hospital, where repeated transfusions of whole blood were given. In spite of this, he remained periodically unconscious for three days, hemorrhage continuing throughout this period. With cessation of bleeding, he was readmitted to the Medical Center as soon as it appeared that he could tolerate the move. Decision to carry out resection was based on the failure of splenectomy, the demonstrated absence of either generalized portal hypertension

or cirrhosis and the persistent threat of exsanguination represented by demonstrated esophageal varices. On August 21 the lower third of his esophagus and the upper two thirds of his stomach were resected, bowel continuity being established by means of esophagogastrostomy. His postoperative course was complicated by an excessive left pleural effusion and a prolonged moderate elevation of temperature; however, he was discharged from the hospital on his twenty fourth postoperative day without any major complications. No further hemorrhage has occurred.

CASE 3.—G. O., a 12 year old boy, was admitted to the Medical Center in January 1949 with a history of severe bleeding from the gastrointestinal tract, beginning at the age of 4 years. Since then he had rarely been free of bleeding for more than a few weeks at a time. In October 1943, at 6 years of age, splenectomy had been performed, with almost no remission. Both minor and major bleeding

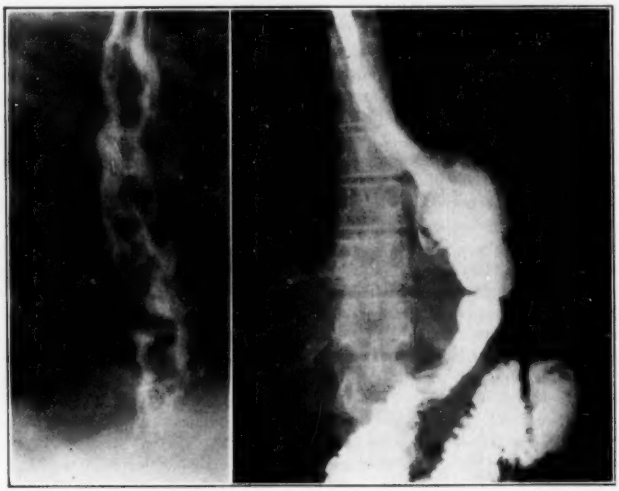

Fig. 1 (case 3).—Esophageal varices at left and postoperative appearance of residual esophagus and stomach at right six months after operation.

episodes continued, the last one beginning two months prior to his admission to the Medical Center, which occurred in January 1949. With this last episode he had been kept alive in his local hospital only by the use of massive whole blood transfusions which have been administered via all superficial veins, including the jugulars, the femoral arteries and the sternum. Bleeding continued after his admission. Pallor and emaciation were the only positive physical findings. The liver was not palpable. Laboratory studies revealed a red blood cell count of 2,200,000, a hemoglobin content of 6 Gm., a white blood cell count of 8,700 and a platelet count of 470,000. His total plasma protein level and albumin-globulin ratio were normal. No retention of sulfobromophthalein was demonstrable. Cephalin flocculation and thymold turbidity tests gave negative reactions. A slight decrease in hippuric acid synthesis was noted. Fluoroscopic examination revealed the presence of many large varices in the distal end of the esophagus. Whole blood transfusion therapy

was continued, and on Feb. 1, 1949, the lower third of his esophagus and proximal two thirds of his stomach were resected, bowel continuity being restored by means of esophagogastrostomy. His liver appeared grossly normal at operation and on biopsy showed no evidence of cirrhosis. He enjoyed an uneventful postoperative course and was discharged on his twelfth postoperative day. Bleeding has not recurred.

CASE 4.—D. S., a 16 year old girl, first bled in 1936, at 3 years of age. Massive bleeding had occurred repeatedly at short intervals since that time. In 1939, at 6 years of age, a huge spleen was reported to have been removed without appreciably altering her clinical course. She was admitted to the Medical Center on April 25, 1949, with a history of having had nine major bleeding episodes since the first of the year, the last one being on March 29 and lasting for nine days and the one before that on March 23 and lasting for six days. Her life had been spared only by the generous use of whole blood transfusions, the family having lost count of these after the first hundred. Physical examination revealed nothing remarkable. Laboratory studies revealed a red blood cell count of 3,680,000, a hemoglobin content of 9.5 Gm. per hundred cubic centimeters, a white blood cell count of 7,450 and a platelet count of 234,000. She had a normal plasma protein level and albumin-globulin ration. Cephalin flocculation and thymol turbidity tests elicited negative reactions. There was slight retention of sulfobromophthalein and a slightly decreased synthesis of hippuric acid. Roentgenograms revealed many huge varices in the distal portion of the esophagus. On May 5, 1949, she underwent resection of the distal third of the esophagus and the proximal four fifths of the stomach, bowel continuity being established by means of an esophagogastrostomy. She enjoyed an uneventful course and was discharged on the eighteenth postoperative day. Bleeding has not recurred.

CASE 5.—T. G., a 22 year old married woman, was first admitted to the Medical Center in October 1948 with a diagnosis of bleeding duodenal ulcer. She gave a history of scarlet fever at 12 years of age without complication. When 17 years old, she had experienced vague abdominal distress, relieved by alkali. At this time the diagnosis of duodenal ulcer was first made. Roentgenologic examinations were not performed. At 18 years of age, without premonitory symptoms, she vomited approximately 1 liter of bright red blood. This occurred again when she was 19½ years old. In April 1948, at the age of 21, she had three separate bleeding episodes, with the loss of at least a liter of bright red blood on each occasion. She became pregnant in June 1948. In September 1948 she had a massive hemorrhage of approximately 3 liters of bright red blood by mouth, after which she passed voluminous tarry stools for one week and required transfusion therapy. It was this attack which occasioned her admission to the Medical Center in October 1948. Roentgenologic studies failed to reveal the presence of a duodenal ulcer; however, many huge varices were demonstrated in the distal portion of the esophagus, both on roentgen examination and on esophagoscopy. On physical examination her spleen was found to occupy the entire left upper quadrant of her abdomen, while the liver was questionably palpable. The red blood cell count was 3,000,000, the hemoglobin content 7.5 Gm., the white blood cell count 3,700 and the platelet count 110,000. She had a normal total plasma protein level, albumin-globulin ratio, serum bilirubin and urine urobilinogen levels. Cephalin flocculation was 3 plus, and there was a slightly increased thymol turbidity, with a slight decrease in hippuric acid synthesis. It appeared advisable to delay intervention until completion of the patient's pregnancy; so she was discharged home. Repeated major episodes of bleeding occurred during the latter months of pregnancy and after delivery, many transfusions being required. She was readmitted to the Medical Center in June

1949, at which time she underwent resection of the distal third of the esophagus and the upper half of the stomach, together with a markedly enlarged spleen, which measured 16 by 11 by 5 cm. Her liver did not appear cirrhotic on gross examination. She enjoyed an uneventful postoperative course and was discharged home on her twelfth postoperative day. Bleeding has not recurred.

A sixth patient is included in this report since she was subjected to the same operative management for what we thought was a clinical syndrome similar to the one just described but at operation was found to have far advanced portal cirrhosis.

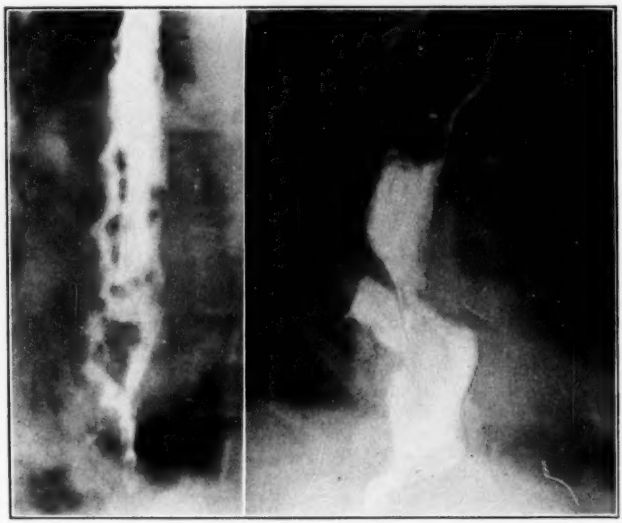

Fig. 2 (case 6).—Esophageal varices at left and postoperative appearance of residual esophagus and stomach at right three months after operation.

CASE 6.—D. K., a 36 year old woman, was well until July 1948, at which time she noticed the onset of weakness and easy fatigability. Her attending physician advised hospitalization. This resulted in her first admission to the Medical Center, where she was observed for two weeks during August 1948. The principal physical finding was a markedly enlarged spleen and a slightly enlarged liver. Laboratory studies revealed a red blood cell count of 5,680,000, a hemoglobin content of 15.5 Gm., a white blood cell count of 4,100 and a platelet count of 88,000. The total plasma protein level and albumin-globulin ratio were normal. Sulfobromophthalein excretion and hippuric acid synthesis were within normal limits. She was found to have a 2 plus cephalin flocculation and markedly increased thymol turbidity. Many large varices were observed at fluoroscopy. A diagnosis of either Banti's disease or portal cirrhosis with secondary hypersplenism was made. During the following year, in spite of intense medical management and careful observation,

her leukopenia and thrombocytopenia progressed and it was feared that her first hemorrhage would probably be fatal. For this reason we elected to carry out esophagogastric resection and splenectomy. She was readmitted to the Medical Center, and on Aug. 17, 1949, the distal third of the esophagus and the proximal two thirds of the stomach were resected together with a markedly enlarged spleen. The liver presented the typical gross appearance of portal cirrhosis, and she had obvious portal hypertension. Postoperatively the leukopenia and thrombocytopenia promptly disappeared; however, she had a stormy course, characterized by migratory superficial and deep thrombophlebitis of all extremities complicated by repeated small pulmonary infarcts and excessive pleural effusion. With anticoagulant therapy she finally became free of thromboembolic disease and left the hospital on October 23. Since then she has steadily improved but still has some difficulty with regurgitation of gastric content through the patulous stoma of the esophagogastrostomy. Fluoroscopic study, made three months after operation, failed to show varices (fig. 2).

COMMENT

Admittedly these patients have been followed for too short a time to warrant any consideration of eventual results. However, if the total result were only the spectacular palliation which has been obtained in several of these desperately afflicted persons, all who have been intimately concerned with their problem would agree that the procedure was justified. Recurrence of bleeding in 1 patient (case 1) is discouraging, although this child presented a complex clinical problem with possibly significant factors not present in the other 4 patients. In case 6, theoretically, varices should reform at the site of the esophagogastrostomy unless there is an opportunity to relieve the portal hypertension by means of a portacaval shunt. That varices are not now present in this case is clearly demonstrated in figure 2, which is a reproduction of an roentgenogram made three months after operation.

SUMMARY

This report concerns the use of partial esophagogastrectomy in the treatment of 6 patients with esophagogastric varices, 5 of whom presented the clinical picture of Banti's syndrome and 1 of whom had portal cirrhosis. No operative deaths occurred. Only 1 of the 6 patients has experienced recurrence of bleeding, this taking place one and one-half years after resection. Death due to hemorrhage occurred in this child three months later.

DISCUSSION

DR. LEWIS GUNTHER, San Francisco: Dr. Mathewson has presented the argument in favor of approaching these lesions which lie high in the esophagus from the right side instead of from the left. He has done this very ably and convincingly and has a series of cases which back up his arguments.

I have approached these lesions, as Dr. Mathewson has, from both sides, and there is no question whatever that the approach from the right is much simpler technically so far as the lesion in the esophagus is concerned. I make one variation

which perhaps is not too important, but I like to approach the lesion that I am operating on first. If you twist the patients on the table a little, with a sand bag under the right shoulder and a table which will tilt from side to side, you can have them draped for both the thoracic and the abdominal procedure. We carry out the transthoracic approach first, from the right, to determine the operability of the lesion itself.

I agree with Dr. Mathewson, as all of you do who operate on carcinoma of the esophagus, that most of the lesions really are inoperable in the sense that there is no chance for a cure. That is one of the most distressing things about operating on these carcinomas. We do not see them early enough. I believe in the palliative operation for carcinoma of the esophagus, but nevertheless I have backed out from the right pleural cavity in the face of extensive local involvement and have then not done the abdominal procedure. So perhaps that variation presents some advantage over exploring the lesion from the abdominal side first.

I encountered a case which presented some difficulties as a result, I think, of this particular type of approach. The patient was an elderly woman who had a tremendously enlarged liver, particularly the left lobe, which was extremely hard. When we came to perform the abdominal exploration and to try to free the stomach, we were unable to shift the liver at all. The operation was accomplished, but the patient died, and the autopsy showed a compression of the stomach by this hard, firm, fixed, enlarged liver. In this case the approach from the left side might have been the better procedure.

Dr. Harold L. Thompson, Los Angeles: The papers by Dr. John T. Reynolds and his associates and those by Carlton Mathewson and Paul W. Schafer have been valuable contributions to the surgery of the esophagus. In the postoperative care of the esophagectomized patient it has been our custom in recent years to employ catheter aspiration of the tracheobronchial tree whenever it was indicated and when we were in doubt. The development of this technic has almost entirely eliminated the necessity for bronchoscopic aspiration. We have not had to employ tracheotomy, but in 2 cases in which I can recall that it was not possible to insert the tracheal catheter this doubtless would have been a valuable procedure. In neither case, however, did an ultimately unfavorable result occur.

Neither have we had occasion to employ the right transthoracic approach to lesions of the middle third of the esophagus as described by Dr. Mathewson. On the other hand, Dr. Eugene Joergenson and I have had 2 cases of esophagogastric varices in which we employed transgastric ligation of the varices, with excellent immediate results. In both instances, however, subsequent hemorrhages occurred. In one instance these hemorrhages have been easily controlled for a period of two and one-half years by the injection of sclerosing solution.

A year ago I reported before this Association a series of 16 personal cases of surgery of the esophagus with a mortality of 35.3 per cent. Data on these cases indicate that J. S. B. has not been followed, W. B. P. died of massive gastrointestinal hemorrhage twenty-eight months after resection of a large chronic peptic ulcer of the esophagus, R. G. D. is working twenty months after resection of a grade 2 carcinoma of the middle third of the esophagus and now weighs 130 pounds (59 Kg.), representing a gain of 9 pounds (3.6 Kg.), E. N. B. is able to do light work after excision of a leiomyosarcoma, recent gastroscopy having disclosed no evidence of recurrence, and A. M. S. is living and well twelve months after total gastrectomy for reticulum cell sarcoma.

One patient operated on, on Dec. 8, 1948, was dismissed from the hospital on the thirteenth day. He resumed violent exercise against advice and a few days

afterward a fistula appeared. He died twenty-three days after operation as a result of separation at the anastomotic suture line.

I am now able to supplement last year's report with data on 10 consecutive cases in which there was 1 hospital death, or an operative mortality of 10 per cent, as shown in the accompanying tabulation.

Type of Operation	Cases	Deaths
Resection with esophagogastrostomy	6	1
Excision of leiomyosarcoma	1	0
Resection with esophagojejunostomy	2	0
Cardiolysis	1	0
Total	10	1

Mortality, 10%

It is to be noted that the rate of resectability in the entire group was 82.3 per cent.

PROBLEMS ASSOCIATED WITH SURGERY OF THE HEART AND THE GREAT VESSELS

Technical Problems Encountered in Surgery for Congenital Abnormalities

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THE OBJECT of this paper is to present some of the technical difficulties encountered in sixty-seven operations performed for congenital cardiovascular lesions during the past twenty months. The history of the advance in this field of surgery and the methods of diagnosis can be obtained from the bibliography.

PROBLEMS COMMON TO CONGENITAL CARDIOVASCULAR SURGERY

Anticipation of difficulties during surgery is of prime importance. The patient must be in as good a condition as possible, and there must be adequate blood available and one member of the team ready at all times to administer it as rapidly as needed. The anesthetist and the surgeon should be in complete accord and must have confidence in each other. Well trained surgical assistants and surgical nurses are essential. Surgery on dogs again has proved itself a necessary part of the experimental surgical department; without it the technic and team work required to prepare for such operations could not have been accomplished.

A cannula is fixed in a vein while the patient is being anesthetized, and it is made certain that it is functioning at all times. The cannula must be large and firmly placed so as to withstand rapid administration of blood.

In all surgical procedures and especially those for congenital cardiovascular lesions, an adequate and generous exposure is important. This

From the Cook County Children's Hospital, Presbyterian Hospital and Mount Sinai Hospital.

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Dr. C. D. Anderson, Chairman of the Department of Anesthesia at The Presbyterian Hospital, Chicago, and Dr. Ruth Weyl, Chairman of the Department of Anesthesia at the Mount Sinai Hospital, administered the anesthetics at their respective hospitals. Credit is due to Drs. C. Lundy, G. Stuppy, H. Sanford, O. E. Gray, M. Dickey, O. Paul and J. Campbell at the Presbyterian Hospital, Chicago, for their diagnoses and assistance.

is usually obtainable through a lateral approach traversing the interspace directly over the area to be surgically attacked. Division of ribs above and below this incision is performed if there is not sufficient room in which to work.

The thoracic duct may be injured, and this occurred during dissection about the aorta and the left subclavian artery in an adult. Ligation of the duct was adequate treatment.

Closed pleural drainage is instituted in each case by means of a Pezzer catheter attached to a sterile water-sealed syphon system. The next morning, if the roentgenogram shows a clear chest with lungs well expanded (with the patient in an upright position), the catheter is removed. Three days is the longest period in which drainage has been maintained.

Aspiration of the pleural cavity has been necessary in 2 cases, in 1 four times and in the other once. We believe that the closed intrapleural drainage has aided greatly in decreasing intrapleural postoperative complications.

PATENT DUCTUS ARTERIOSUS

The patients with the patent ductus arteriosus which we have operated on have ranged in age from 2 to 36 years. The problems multiply many times with the advancing years. There is no doubt that the optimum time for surgery is in early childhood, while the vessels are elastic and vascular degenerative changes have not taken place and before bacterial aortitis and endocarditis have developed.

The first 4 patients operated on were children 2 to 8 years of age. All had the ductus tied triply with suture ligatures of heavy silk (fig. 1 *A*). The third patient, a girl of 7 years, had a recurrence in two months' time. Since that time we have followed the advice of Dr. R. E. Gross and changed the method to division of the ductus and suturing of the divided ends (fig. 1 *B*). A year after the recurrence referred to we were able to divide and suture the ends of the ductus. Thus in the 23 patients operated on there have been excellent results.

The chest is entered through the left third interspace laterally, the skin incision being placed below the breast. The mediastinal pleura is freed from the aorta for approximately 3 inches (7.6 cm.) from the first portion of the left subclavian artery and from the vagus nerve, which is gently retracted (to one side or the other as needed) with the aid of a small Penrose drain. In the adult the aorta is freed so that an aortic clamp can be used in case of emergency and in cases in which the ductus is short and wide. The aortic clamp (fig. 1 *C*) has been required in 2 cases, during the division of the recurrent ductus and in a 24 year old woman with a short, wide, sclerotic ductus. We have also found it of great help to have the pulmonary artery well exposed for some distance on either side of the insertion of the ductus, particularly in

adult patients and in those with a short wide ductus. The large pulmonary artery can then be encroached on in order to have adequate terminal cuffs to suture at the divided ends of the ductus.

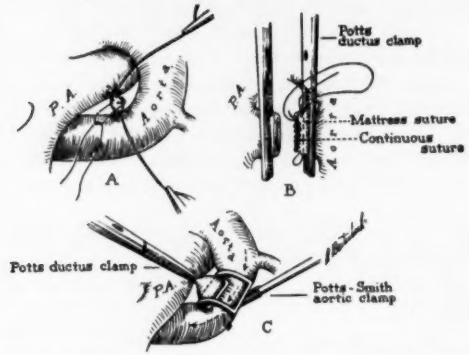

Fig. 1.—Three methods used in the ligation or division of the ductus arteriosus. *A*, in the first 4 cases triple suture ligatures were used. One patient had a recurrence two months postoperatively. *B*, seventeen ductus were divided and sutured as shown. *C*, two ductus were divided and sutured as shown; one was short and wide, and one was recurrent.

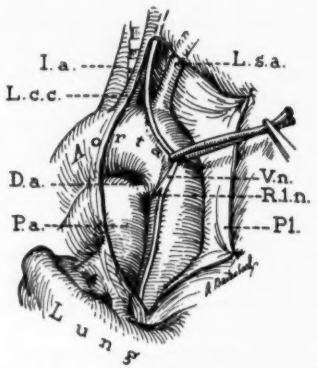

Fig. 2.—Drawing shows the vagus nerve and its recurrent branch well exposed and gently retracted. The aorta and the pulmonary artery and ductus are well visualized. There have been no recurrent nerve injuries in our series.

The problems which we have encountered in adults with patent ductus arteriosus are severe hemorrhage at operation, postoperative hemorrhage, sclerosis of the ductus and the aorta, aneurysmal dilatation

of the aorta at the site of the ductus, bacterial aortitis and endocarditis and cardiac arrest followed by prolonged hypotension.

Hemorrhage occurred on two occasions while the ductus was being freed, in female patients aged 24 and 36. Each had a thin-walled, sclerotic ductus which tore easily. In the first case the hemorrhage was well controlled with the Potts-Smith aortic clamp on the aorta, and the ductus was then clamped on the pulmonary side. In the second case there was an aneurysmal dilatation of the aorta to 3 inches (7.6 cm.) in width at the level of the ductus. None of the aortic clamps was of adequate size to apply, nor did we feel that this sclerotic fusiform swelling would tolerate clamping such as described by Dr. Crafoord. Therefore, with digital pressure at the injured site, the rest of the ductus was freed and clamps then applied, the ductus divided and the ends sutured. During both of these procedures blood was administered rapidly, and totals of 6 and 8 pints (3,000 and 4,000 cc.), respectively, were necessary for blood replacement.

The only postoperative hemorrhage which we have encountered occurred in the 24 year old patient mentioned. At 8 p. m. on the day of operation the left pleural cavity was found to be full of blood and 1,800 cc. was removed. Then transfusions were given, and the patient's appearance improved for four hours, after which she again presented the picture of hemorrhage. She was taken to the operating room, the chest was opened and free blood and blood clots were removed. Hemorrhage was found to be coming from many small vessels in the chest wall and the mediastinum. These small vessels did not appear to have normal retractile qualities and were seen protruding from their various locations. Considerable time was required to accomplish hemostasis. Intercostal drainage was reestablished for three days. Aspiration of the pleural cavity was required four times. She has made a satisfactory recovery.

Aneurysmal dilatation of the aorta occurred in a 30 year old man with associated bacterial endocarditis and aortitis and in the 36 year old woman previously referred to who also had considerable cardiac enlargement. This condition may be more frequent than the literature indicates. Aneurysms of the ductus and pulmonary arteries are commonly referred to, but to date we have not encountered a discussion of a spindle or fusiform aneurysm of the aorta at the level of the ductus. In both cases the ductus was wide and at right angles with the aorta. Both aortic aneurysms were thick and sclerotic. Both of these patients have made excellent recoveries. The heart size in the 36 year old woman has decreased noticeably during the seven month postoperative period.

Bacterial endocarditis and aortitis occurred in a man 30 years of age who had symptoms of intravascular infection for six months. He had known of his congenital heart condition for the greater part of his life.

Blood cultures of streptococci of the viridans group were reported in the first few days of hospitalization. The preoperative management was conducted by Dr. Earl Gray and Dr. Marvin Dickey.

Penicillin in the form of crysticillin,* 300,000 units, was administered twice daily for six weeks. At the end of this time blood cultures showed no bacterial growth. At operation a fusiform swelling of the aorta at the site of the ductus was found; it was approximately two and a half times the diameter of the aortic arch or the aorta distal to the enlargement. The ductus was 1¼ inches (3 cm.) long and ¾ inch (2 cm.) wide.

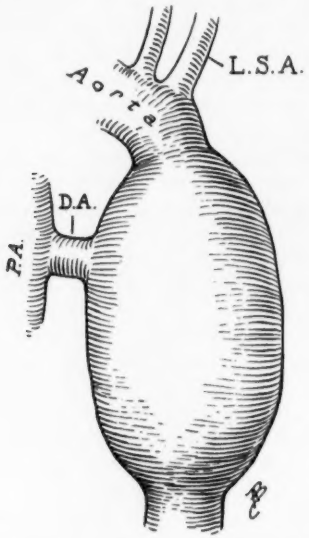

Fig. 3.—This sketch well illustrates the appearance of the enlargement of the aorta at the site of the patent ductus, which is at right angle to it. This was found in 2 patients, a 30 year old man and a 36 year old woman. The walls of the aortas were thick and sclerotic. The ducti were divided and sutured.

The aorta and the pulmonary artery were well freed first. In the event of hemorrhage during dissection about the ductus, control of the situation would then be less difficult. No difficulty was encountered; the large ductus showed no evidence of infection of its wall or lumen. The patient returned to work as a welder six weeks after the operation.

Cardiac arrest occurred while the ductus was being freed in a 22 year old woman. Rhythm was reestablished in less than a minute, but in spite of infusion of blood and an increase in oxygen administration, the blood

pressure remained so low that surgical intervention was halted for approximately an hour, after which it was felt safe to complete the operation.

TETRALOGY OF FALLOT AND TRICUSPID ATRESIA

The surgical problems which we have encountered in cases of tetralogy of Fallot and tricuspid atresia are divided into six groups and concern thirty-five operative procedures.

1. The small infants with severe oxygen need, aged 19 days, 7½ weeks, 10 weeks and 5 months and weighing from 7 to 9 pounds (3.2 to 4 Kg.), had conditions diagnosed as "tricuspid atresia" or nonfunctioning right ventricle. All 4 were treated successfully by means of pulmonary artery–aorta anastomosis. Technically the operations were not difficult. Good anesthesia and gentleness in handling are essentials. The small Potts-Smith clamp was satisfactory in occluding partially the aortas, which were of the diameter of a lead pencil. In all cases the small (3 to 4 mm. in diameter) pulmonary arteries were adequate for the anastomosis. A mastoid retractor was used in the last case and found to be of help in that it was light in weight and served to spread the ribs adequately. The Potts-Smith procedure will give these infants, for whom there was previously no hope, an opportunity for life.

2. Patients with a right aortic arch have presented the commonest technical difficulties in the formation of an adequate ductus.

A 5 month old infant girl in severe oxygen need and having a right aortic arch was benefited by a Potts-Smith procedure for one year. We do not believe that this operation is indicated for the older patients with a right aortic arch because the vessels to be anastomosed are at right angles with each other, making it difficult to obtain a satisfactory fistula. Thirteen months after this first procedure, a Blalock operation was performed through the left side of the chest which has given a satisfactory result.

In a 13 year old girl with a right aortic arch the left subclavian artery arose in the right side of the mediastinum and crossed to the left behind the esophagus at the apex of the left thoracic cavity. The Blalock procedure, which is usually easily carried out on the left side, could not be done. Three months later a Blalock operation on the right side gave the patient relief from symptoms due to oxygen need.

A severely ill girl of 3 years of age with a right aortic arch, frequently semicomatose and requiring constant oxygen therapy, was operated on shortly after the preceding patient. Because of the previous experience and the realization that this child would not withstand any surgical procedure unless the oxygen content of the blood was increased, the right side of the chest was entered, in the belief that either the Blalock

or the Potts-Smith procedure could be accomplished. The subclavian artery–pulmonary artery anastomosis was satisfactorily completed. The pulmonary artery–aorta anastomosis in this case could not have been done because the right arch passed to the left at a location which would have made the artificial ductus operation at this site impossible.

In a girl 13 years of age with a right aortic arch marked hypotension developed while the mediastinal pleura was being freed from the left innominate and subclavian arteries. The surgical procedure had to be discontinued. Seven months later the right side of the chest was opened and the right subclavian artery was found to be too short to anastomose to the pulmonary artery. The upper branch of the pulmonary artery was freed and ligated at its origin from the main pulmonary artery. An end to end anastomosis was then completed between the subclavian artery

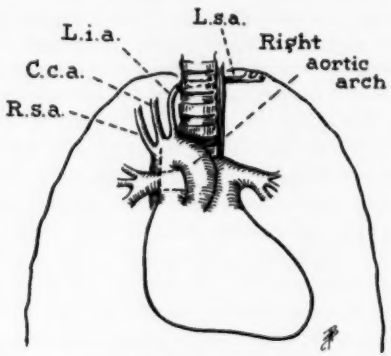

Fig. 4.—Right aortic arch with the left innominate artery arising on the right and the left subclavian artery crossing under the esophagus at the apex of the left chest cavity. A Blalock procedure on the left was impossible but was successful at a later date through the right chest cavity.

and the distal branch of the pulmonary artery. This procedure has given a satisfactory, but not a perfect result.

3. A tetralogy of Fallot with an associated vascular ring was diagnosed and confirmed at operation in a 17 month old child who had an anomalous right subclavian artery originating in the distal portion of the aortic arch and passing upward to the right and posteriorly to the esophagus. This vessel was doubly ligated near its origin and divided and the distal end allowed to retract to the right of the esophagus, and thus the constriction due to the vascular ring was relieved. The pulmonary artery–aorta anastomosis was then completed (fig. 6 *B*).

4. A nonfunctioning artificial ductus was noted on two occasions after removal of the aortic clamp. The vessels were again occluded, and

the anterior row of sutures was removed. In the case of a 9 month old infant no clot or misplaced suture was found. In retrospect it is believed that hypotension at that time did not allow for the usual thrill at the site of the ductus. In the second case, however, a small thrombus was revealed at the opening, and a suture in the anterior row was caught on a

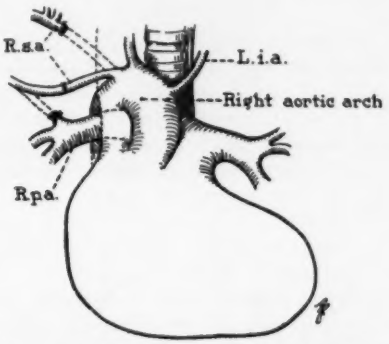

Fig. 5.—Right aortic arch. The right subclavian artery was too short to anastomose to the pulmonary artery. An end to end anastomosis between the subclavian artery and the superior branch of the pulmonary artery has given a satisfactory result.

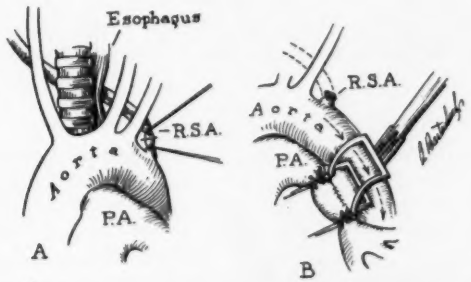

Fig. 6.—Anomalous right subclavian artery arising on the left side and passing upward and posterior to the esophagus. It was tied and divided as shown and the distal end encouraged to retract to the right of the mediastinum. *B*, the Potts-Smith operation was then done as illustrated for relief of a tetralogy of Fallot.

suture of the posterior row, thus closing the lumen. In each case another anterior row of sutures was carefully placed and the desired thrill followed the release of the vessels.

5. The size of the anastomosis when the Potts-Smith procedure is being used has not been definitely worked out. We believe that an

opening of 5 to 6 mm. in the aorta is usually satisfactory. A 6.5 mm. opening in the aorta proved too large for an 18 month old child. She died of cardiac failure three months after operation. Postmortem examination revealed a functioning artificial ductus, a tetralogy of Fallot and a large interauricular septal defect. Death was due to cardiac failure. It is better, we believe, to have the artificial ductus a little too small than too large.

6. The type of approximating suture used in performing the anastomosis depends on the case. If it is more convenient to use the running over and over suture, that is done. We believe that good approximation of the vessel wall is necessary, and either lock stitches or interrupted sutures should be used to prevent a purse-string effect of the running suture. The Potts-Smith procedure uses the running over and over suture. The everting mattress stitch is most often employed in the Blalock procedure.

Thirty-one operations have been performed for tetralogy of Fallot and four for tricuspid atresia. In our experience the Potts-Smith procedure was successful in patients from 19 days to 8 years of age and the Blalock procedure successful in patients from 1½ to 24 years of age.

Five of the 6 patients who died were 2 years of age or under. One died of cardiac failure three months after surgical intervention, 1 of postoperative cerebral thromboses, 1 of cerebral hemorrhage, 1 of multiple thromboses and 1 of cardiac arrest during operation. The sixth patient, a 24 year old woman, died of cardiac failure six weeks after operation. The mortality rate for these abnormalities is highest in the first year of life, and few infants survive without surgical intervention.

DOUBLE AORTIC ARCH AND VASCULAR RING

The experience which we have had with congenital vascular rings is limited to 3 patients 7, 18 and 24 months of age. All had a history of repeated respiratory difficulty, pneumonia and stridor of varying degrees. Difficulty in swallowing was also common to the 3 cases. The diagnoses were made by Dr. Benjamin Gasul. The esophagrams showed filling defects caused by the anterior and posterior arches in 2 cases constricting the esophagus, and by an anomalous right subclavian artery arising on the left and passing obliquely upward to the right arm posterior to the esophagus.

The approach through the left side of the chest is easier technically than that through the right. One of the 3 patients, aged 8 months, did not tolerate the first attempt at surgical intervention in the left pleural cavity. At a later date the right side of the chest was opened and the procedure completed. The large veins to the right auricle made the dissection in the right side of the mediastinum more difficult than is usually the case.

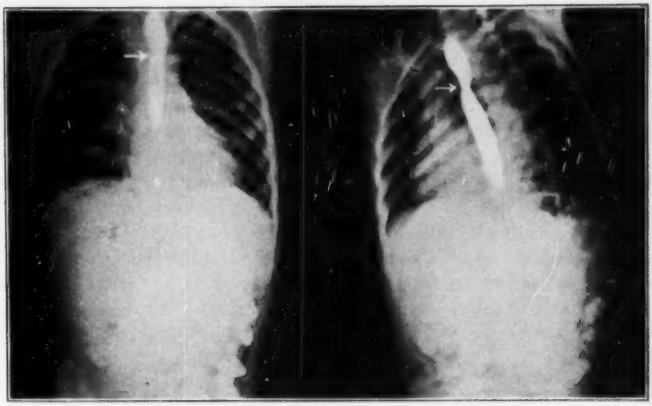

Fig. 7.—The filling defects in the esophagus as shown in the anteroposterior and lateral esophagrams are typical of a double aortic arch.

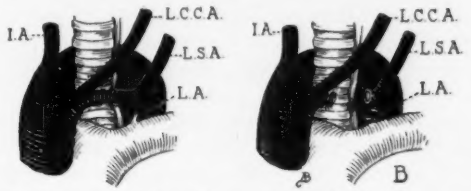

Fig. 8.—Double aortic arch found in a patient aged 2 (esophagrams in figure 7) who was confined to a hospital for all but three months of his life because of recurrent pulmonary infection. He had difficulty swallowing and breathing. *B*, the small anterior arch and the ligamentum arteriosum were ligated and divided, and the constriction was relieved.

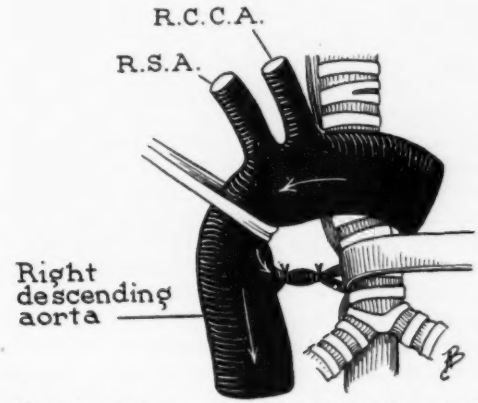

Fig. 9.—Illustration of a large anterior and small posterior arch. The posterior arch was ligated and divided, giving freedom to the esophagus and trachea.

The object of the procedure is to release the constriction of the esophagus and trachea caused by the vascular ring. In case of the double aortic arch, the smaller portion of the arch is ligated and divided, thus allowing the trachea and esophagus freedom at this previously constricted site. The 2 cases varied in that the anterior portion of the ring was small in the 2 year old child while the posterior arch was small in the 7 month old child. In the third patient with a vascular ring ligation and division of the anomalous right subclavian artery at its origin was carried out (fig. 6). The distal portion was freed so that it could retract to the right of the mediastinum, relieving the pressure by the vessel on the posterior wall of the esophagus. These are gratifying operations.

COARCTATION OF AORTA

Problems associated with surgery for coarctation of the aorta are increased with the age and size of the patient. Our surgical experience is limited to 5 patients ranging in age from 9 to 24 years; there were 4 males and 1 female. The increased collateral circulation in the chest wall and the arteriosclerotic changes in the late adolescent and adult groups make the results of the operation questionable. The ideal period for operation, we believe, is before adolescence, and it may be wise to resect the stenotic areas of the young child, using an absorbable suture for the anastomosis, as suggested by Dr. Sidney Smith, so that growth of the lumen can take place with growth of the rest of the body. Arteriosclerosis above and below the coarctation was present at the ages of 9 and 13 years and marked at 24 years of age.

The surgical procedure which we follow is that of Dr. R. E. Gross and Dr. Crafoord, and their teachings have made possible the success in these 5 cases. Mobilization of the aorta and aortic arch, left subclavian artery and the intercostal arteries as completely as possible to at least 4 to 6 inches (10 to 15 cm.) below the stenosed aorta is essential to satisfactory resection and anastomosis. When these are freed, the ligamentum arteriosum is ligated and divided. This should allow for adequate mobilization.

Injury to and prolonged occlusion of the collateral circulation should at all times be avoided. In our first case the stenosis was just distal to the junction of the aortic arch with the left subclavian artery. It was necessary to clamp separately the arch and the subclavian artery during the resection and anastomosis. The Blalock modification of the Potts-Smith aortic clamp and the Potts coarctation clamp are instruments that will aid in preserving the collateral circulation.

One intercostal artery was sacrificed in each of 4 cases, but the other intercostal arteries for 4 to 6 inches (10 to 15 cm.) below the coarctation were well mobilized and protected from injury. Two intercostal arteries

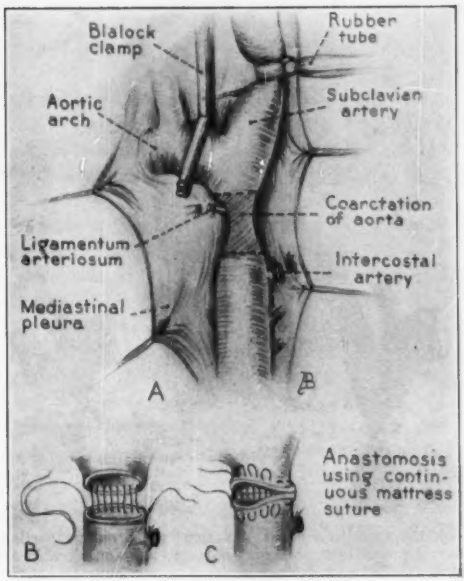

Fig. 10.—Drawing made at operation, showing the method used to clamp the aortic arch and the left subclavian artery in preparation for resection of the coarctation. This is not a good procedure because it interferes with the collateral circulation by way of the left subclavian artery. One intercostal artery was sacrificed to allow for adequate mobilization.

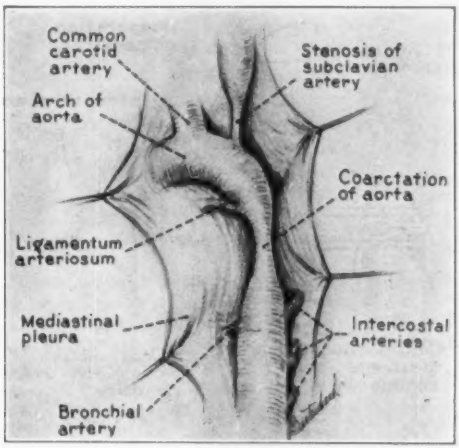

Fig. 11.—Drawing made at operation shows a long narrow coarctation and a stenosis of the left subclavian artery in a boy 13 years of age. A resection of the coarctation of the aorta and an end to end anastomosis have given an excellent result.

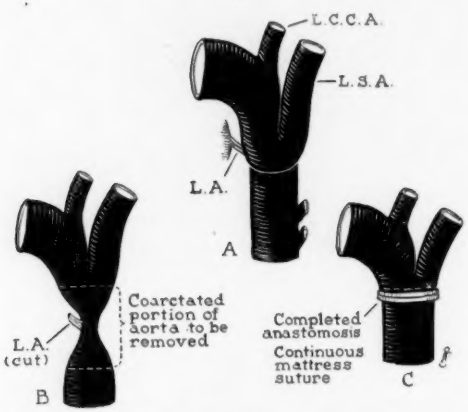

Fig. 12.—*A*, the aorta as seen at operation; the proximal portion overlay the stenosed area. *B*, the patient, a 9 year old boy, had considerable arteriosclerotic changes of the aorta.

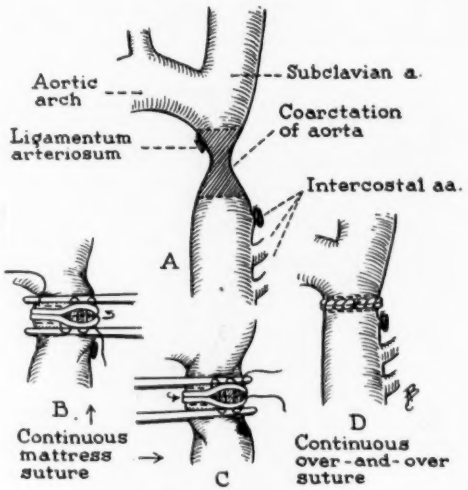

Fig. 13.—Technic carried out in 4 cases.

were sacrificed in the fifth case because of a long narrowed stenotic area. In this patient the systolic blood pressure in the left arm was 40 mm. of mercury less than that in the right arm. At surgery a stenosis at the origin of the left subclavian artery was found and was the cause of this difference.

A 9 year old boy with systolic blood pressure of 200 mm. of mercury at operation had a dilated proximal aorta that overlay the stenosed vessel. The vessel both above and below the constriction was thin walled and sclerotic, and while it was being freed from the ligamentum arteriosum it tore at the ligamental insertion. Ligatures around the aorta above and below the ligamentum controlled the hemorrhage and added slightly to the length of the stenosed segment resected.

The method of anastomosis used employs two rows of sutures. The first is a continuous row of everting mattress sutures. A definite attempt should be made to have the sutures close together but unevenly placed from the ends of the vessels, so that the tension will not be on the same line in the circumference of the vessel. In the laboratory we have shown that when the suture line is under considerable tension the sutures hold but the aorta gives way at the line of perforation of the vessel by the sutures. The more evenly the suture line is placed the more prone is the vessel wall to separate. The second row of sutures consists of running over and over stitches.

Dr. Gross and Dr. Crafoord have presented procedures that, when used in childhood, should convert seriously handicapped patients to normal.

SUMMARY

Some of the problems encountered during sixty-seven surgical procedures for the relief of congenital cardiovascular anomalies are discussed, such as patent ductus arteriosus, tetralogy of Fallot, tricuspid atresia, coarctation of the aorta and vascular rings.

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Anesthetic Problems in Children Undergoing Operations on the Heart and the Great Vessels

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Surgical intervention for such congenital anomalies as patent ductus arteriosus, double aortic arch, tricuspid atresia, coarctation of the aorta and tetralogy of Fallot is most apt to be successful when a skilled team exists consisting of cardiologist, surgeons, anesthesiologist, operating room nurses and personnel rendering postoperative nursing care.

Many problems arise from the anesthetic standpoint in the management of patients with these conditions, and it is my intention to report experiences gained from handling 36 patients on whom forty operations were performed. All offer a challenge but none as great as that offered by the patient undergoing an operation for the relief of a tetralogy of Fallot or of tricuspid atresia.

PREOPERATIVE MANAGEMENT

Every effort is made to bring patients to the operating room in the best possible condition. In most instances it is feasible to delay operation until optimum conditions exist, but this is not invariably the case. Some patients who have a tricuspid atresia or a tetralogy of Fallot are so acutely ill that surgical intervention is made as an emergency measure, irrespective of the fact that these patients are the poorest risks. Nevertheless, heroic measures have proved life-saving in more than one instance, the gratifying results justifying the decision which had been made.

The hypoxic state of children with tricuspid atresia and tetralogy of Fallot makes it necessary to depress metabolism so that a decreased demand for oxygen exists. This is usually achieved with the use of moderately heavy doses of morphine. The size of the dose is determined by the age and weight of the patient. Morphine is used not only to lower oxygen requirements but also to lessen the amount of anesthetic agent necessary, as well as to facilitate the use of controlled respiration during the operation. In addition to morphine, relatively large doses of

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atropine are administered to all patients. Not only does atropine inhibit the formation of secretions but it also tends to diminish the heightened vagal reflex activity which is initiated by such agents as cyclopropane and thiopental sodium. In summation, the end result of the premedication should be the production of a drowsy patient whose resistance to the anesthetic agent will be minimal and whose vagus nerve mechanism is depressed to a degree that harmful reflex phenomena are lessened considerably.

CHOICE OF ANESTHETIC AGENT AND METHOD

It must be stated at the outset that no one agent or method is to be recommended in a dogmatic manner. Various agents and methods have been employed most skillfully by more than a few persons and with completely satisfactory results. What will be discussed, however, is the technic which has proved satisfactory in the hands of my colleagues and me at the Cook County Children's Hospital in Chicago. The agent and method used should insure (1) a rapid induction with a high oxygen tension, (2) a rapid return to consciousness, (3) a patent airway which will eliminate one of the causes of hypoxia and allow the lung to be collapsed or expanded as desired, (4) an operative field undisturbed by respiratory movements and (5) an immediate means to remove accumulated secretions in the tracheobronchial tree.

We have used cyclopropane in all patients with the exception of 1 digitalized patient to whom thiopental sodium and nitrous oxide were administered. Cyclopropane is administered by the endotracheal method using the to and fro absorption technic. Soft rubber endotracheal tubes without cuffs were used in all patients in this series. If the tube fits snugly, no appreciable leak will occur and the desired positive pressure can be maintained.

In order to secure a quiet operative field, controlled respiration is used whenever possible. The absence of respiratory movements of all types renders optimum conditions for the delicate operation that is being performed.

OPERATIVE MANAGEMENT

During the operation two great complications are a constant threat to success: hypoxia and harmful reflexes. The hypoxia may result from an inadequate amount of oxygen being delivered to the patient, either because of an atmosphere deficient in oxygen or of obstruction, or as an ultimate effect of reflex mechanisms. Needless to say, hypoxia must be recognized at the earliest possible moment and the cause remedied immediately.

Increasing the flow of oxygen to the patient will correct an atmosphere deficient in oxygen. The commonest causes of obstruction to the patient's airway are kinking of an endotracheal tube, accumulation of

secretions to such an extent that ventilation is impaired, or pressure on the tracheobronchial tree from too vigorous retracting or packs. Accumulated secretions should be removed several times during the operation. When this is necessary, the operation is momentarily held up while a small catheter is inserted through the endotracheal tube and aspiration performed.

The harmful reflexes encountered are those arising from such acts as spreading the ribs, exploration in the hilar region of the lung or at the base of the heart, traction on the aorta or other great vessels and too vigorous retraction of the lung or heart to secure greater exposure. The effect may be hypotension, reflex slowing of the heart, cardiac irregularities or cardiac arrest. It is felt that blocking three or more intercostal nerves well posteriorly with 1 per cent solution of procaine hydrochloride helps considerably in abolishing harmful reflexes associated with spreading the ribs. Additionally, spreading the ribs slowly further eliminates this danger. It is felt that the application of 5 per cent cocaine to the pericardium, the hilus of the lung and the general vicinity where exploration is to be performed has cut down the incidence of reflex cardiac irregularities.

In the group of cases of tricuspid atresia and tetralogy of Fallot a third serious complication may occur, i. e., cerebral accident Since the red blood cell count is high in these patients, the increased viscosity of the blood makes cerebral thrombosis an ever present hazard. Consequently, bradycardia or hypotension is given prompt attention. For this purpose, 1/800 grain (0.08 mg.) of atropine is given intravenously. This invariably increases the cardiac rate, as well as producing a more vigorously beating heart. If the bradycardia is due to reflex mechanisms, 5 per cent cocaine is applied topically to the hilar region and 1/800 grain of atropine given intravenously.

In all types of operations except those for correction of tricuspid atresia and tetralogy of Fallot, blood is administered during the operation. In the case of the two latter conditions, blood is not administered except for such conditions as hemorrhage, or hypotension not corrected with plasma or the measures previously described. It must be stated that we have no hesitancy in canceling the operation if the patient is not tolerating the anesthesia well or if it appears that continuation of the operation would jeopardize his life. Thus, in three instances the operation was canceled and on subsequent occasions a successful conclusion to the operation was effected. In all these instances the patient had an uneventful recovery.

Reinflation of the lung at periodic intervals during the operation depends on the general condition of the patient as the procedure progresses. In some instances the lungs are not reinflated during the

operation. However, reinflation of the lungs is always carried out just before the pulmonary artery is clamped off preparatory to making the pulmonary artery–aorta or pulmonary artery–subclavian artery anastomosis in patients with tricuspid atresia or tetralogy of Fallot. It is felt that every last bit of oxygen reserve should be afforded the patients during the period when the pulmonary artery is clamped off and the anastomosis is being effected.

Should cardiac arrest occur at any time during the operation, all packs and retractors are removed, 100 per cent oxygen is administered, 5 per cent cocaine is applied to the heart and gentle rhythmic compression of the heart at the rate of 40 to 50 times a minute is carried out. If automatic beating of the heart is not restored in a reasonable length of time, such as twenty to thirty minutes, it is doubtful if further efforts will prove efficacious.

If at any time during the operation the temperature begins to rise, or if the temperature of the room is very high, six or more ice bags are placed about the patient. This has lowered the temperature of the patients and apparently reduces the amount of anesthetic agent necessary.

After completion of the operation, the lungs are reinflated and the pleural cavity drained. Care is taken to remove all accumulated secretions from the tracheobronchial tree before the endotracheal tube is removed, as these secretions would prove to be a probable source of trouble in the postoperative period. All patients should be awake in a matter of minutes after the termination of the operation. When this is not the case, we fear that hypoxic changes in the brain may have taken place and take a pessimistic attitude. Nevertheless, all patients are transported from the operating room in their own beds, while 100 per cent oxygen is being administered.

POSTOPERATIVE MANAGEMENT

The patients lie on the operative side principally during the first twenty-four to thirty-six hours postoperatively. Fluids by vein are carefully administered during the first twenty-four hours. We have not used heparin or other anticoagulants postoperatively. A close watch of the blood pressure and pulse is made. This is most important in the cases of tricuspid atresia and tetralogy of Fallot, in which bradycardia or hypotension may lead to a cerebral thrombosis. Should hypotension develop, fluids and vasopressors to restore the blood pressure are administered. Secretions which accumulate in the pharynx are promptly removed by suction. All patients receive oxygen by tent or catheter for as long as indicated. After the first twenty-four hours they are allowed to remain out of the oxygen tent or the oxygen by catheter is discontinued for longer and longer periods, until administration is discontinued on the third day if the condition warrants it.

In 1 patient in our series a complete hemiplegia developed either during the operation or immediately after. This was in a 13 year old girl in whom it was contemplated to perform a pulmonary artery–subclavian artery anastomosis. Because of persistent hypotension it was decided to discontinue the operation. This patient awoke about twelve minutes after the termination of the operation but was unable to move the left side of her body. Within another five minutes a right stellate ganglion block was performed with 10 cc. of 1 per cent procaine hydrochloride. About five minutes later full use of the left side of her body could be made, and she made an uneventful recovery. It was felt that the hemiplegia was due to anoxia, not sufficient, however, to produce irreversible brain damage. This patient was subsequently brought to the operating room and a pulmonary artery–subclavian artery anastomosis made through a right thoracic approach. Since operation she has been showing steady improvement.

DEATHS

In a paper by M. H. Harmel and Austin Lamont [1] on the mortality rate in 100 patients undergoing pulmonary artery–subclavian artery anastomosis for pulmonary stenosis or atresia, they reported that 23 of the 100 patients died, 5 in the immediate operative period.

Santy, Berand, Bret and Marion [2] reported on 45 operations for correction of congenital cyanosis by means of a pulmonary artery–subclavian artery anastomosis. Ten patients died in this series, 5 of them on the operating table.

McQuiston [3] reported on one hundred and forty-two operations in which a pulmonary artery–aorta anastomosis was attempted or completed. Nineteen deaths occurred in this series from all causes. In this series no anastomosis was possible in 15 patients, 6 of whom died. In the 127 cases in which an anastomosis was possible 13 patients died. In our series of forty operations, the ages of the patients ranging from 57 days to 15 years, twenty-five were for tetralogy of Fallot, two for coarctation of the aorta, three for tricuspid atresia, seven for patent ductus arteriosus and three for double aortic arch. There were no deaths on the operating table. Table 1 shows the deaths which occurred in the various age groups. There were 5 deaths in forty operations, making a mortality rate of 12.5 per cent. Of those in the under 1 year group,

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2. Santy, P.; Berand, M.; Bret, J., and Marion, P.: Forty-Five Blalock Operations for Congenital Cyanosis, Lyon Chir. **44**:129, 1949.

3. McQuiston, W. O.: Anesthetic Problems in Cardiac Surgery in Children, Anesthesiology **10**:590, 1949.

1 patient died within twenty-four hours after operation from cerebral thrombosis. The patient in the 1 to 2 year group survived an operation during which a pulmonary artery–aorta anastomosis was performed. This patient died nine weeks after the day of operation from right heart failure. Three deaths occurred in the 2 to 3 year group. Two of these patients survived the operation, which consisted of a pulmonary artery–aorta anastomosis, but 1 died twenty-four hours postoperatively of multiple thromboses while the other died three days postoperatively of a cerebral hemorrhage. The last death in our series occurred in a boy

TABLE 1.—*Deaths in All Operations*

Age, Yr.	No. of Cases	No. of Deaths
0-1	11	1
1-2	5	1
2-3	7	3
3-4	3	0
4-5	1	0
5-6	1	0
6-7	2	0
7-8	2	0
8-9	1	0
10-11	1	0
13-14	5	0
15-16	1	0
Totals	40	5

TABLE 2.—*Deaths in Patients with Anastomosis for Tetralogy of Fallot*

Age, Yr.	No. of Cases	No. of Deaths
0-1	6	1
1-2	5	1
2-3	4	2
3-4	2	0
6-7	2	0
7-8	1	0
13-14	4	0
15-16	1	0
Totals	25	4

2 years and 3 months old who had a double aortic arch. His death occurred twenty-six hours postoperatively from bilateral recurrent tracheobronchitis.

Table 2 shows the number of deaths in the various age groups of patients in whom an anastomosis between the pulmonary artery and the aorta or one of its branches was made for the relief of a tetralogy of Fallot. All the deaths occurred in patients below 3 years of age.

SUMMARY

The anesthetic management of patients undergoing surgical intervention for various congenital anomalies of the heart and great vessels is presented. The agents and methods employed at Cook County

Hospital for these operations have been discussed. Hypoxia and harmful reflexes are the commonest complications during operation. The mortality rate has been presented and the cause of death in each case discussed.

DISCUSSION

DR. EGBERT H. FELL, Chicago: The anesthetic problems associated with surgery of the heart and great vessels was well presented by Dr. Grem. Team work in all types of surgery is essential, but in cardiovascular surgery the team work between the anesthesiologist and the surgeon must be one of keen understanding and cooperation at all times. We have been fortunate at the Cook County Hospital in having Dr. Grem as the anesthetist on the cardiovascular team. Credit is due to him for an enviable record of no anesthetic deaths in forty consecutive cardiovascular operations on patients ranging in age from 7 weeks to 15 years. This good fortune, I am sure, cannot continue with the type of cases with which we have to deal, but the operative mortality will remain low if the anesthetic agents are administered by such interested and well trained anesthesiologists.

SURGICAL TREATMENT OF TUBERCULOUS PERICARDITIS

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TUBERCULOUS pericarditis, chronic, insidiously progressive, frequently characterized in its early stages by an inflammatory effusion and culminating almost inevitably in great thickening and fibrous contraction of the diseased pericardium, presents real difficulties in its management.[1] From its inception, it poses the twofold problem of controlling infection and of correcting the mechanical interference with the flow of blood imposed by constriction of the heart or its great vessels, most particularly the venae cavae, the compression of which is believed to be the primary reason for the persistent and recurring pleural and peritoneal effusions.

The gravity of the disease is illustrated by the study of Harvey and Whitehill[2]: "Of 20 proven cases with effusion 16 died and of 17 proven cases without an effusion 15 died, a mortality of 83 per cent." Blalock and Levy,[3] after a study of 22 proved cases in 1937, reported: "Every patient, with one exception, with a proved diagnosis of tuberculous pericarditis who has not had a pericardiectomy, is dead." Of the 6 patients operated on for removal of constricting pericardium, "three were cured or markedly improved, and three are dead. Of the latter, one died 6 months after operation of miliary tuberculosis, the second died 2 months following operation, also of miliary tuberculosis, and the third died a few minutes after completion of the operation." Later these authors stated:

> We do not mean to imply that all patients with tuberculous pericarditis die unless a decortication of the heart is performed. Certainly a number of the patients in

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3. Blalock, A., and Levy, S. E.: Tuberculous Pericarditis, J. Thoracic Surg. **7**:132, 1937.

the group in which tuberculous pericarditis was suspected but not proved had the disease and some of them are well. It seems likely that they had a less fulminating type of infection or that their resistance was greater. Also the fact that some of the healed pericardial scars which have been reported were almost certainly tuberculous in origin is evidence that the acute infection is not always fatal. On the other hand, pericardiectomy would seem to be indicated in those individuals who grow worse rather than better as the effusion disappears.

With reference to treatment in general, they stated:

The treatment of tuberculous pericarditis in the acute fibrinous stage consists in the employment of rest in bed and of narcotics for the relief of pain. If and when an effusion develops, it is probably advisable not to perform frequent aspirations except for the purpose of relieving dyspnoea and evidences of marked systemic congestion. It is believed by some that aspiration of fluid followed by replacement with air is of benefit. Everyone is agreed that the pericardium should not be drained during the stage in which an acute effusion is present. When the tuberculous process becomes entirely inactive and evidences of compression of the heart persist, everyone is agreed that the scar should be removed. There is some difference of opinion as to the treatment to be employed when the patient's condition is becoming worse and the venous pressure is rising despite the fact that the heart-pericardial shadow has decreased in size. It is our impression that operation should be undertaken at this time even though the infection is believed to be active. In this regard, Churchill [4] states: "Active tuberculosis of the pericardium may produce the entire syndrome of chronic constrictive pericarditis. The point at issue is whether operation can be effective if performed during the active stage of the infection. The reports in the literature of operations performed during this period are uniformly discouraging and confirm our personal experience." Beck stated recently: "As long as the tuberculosis shows activity, one cannot expect to relieve the cardiac compression."

Two of the patients in Churchill's series had an active tuberculous pericarditis at the time of operation. In regard to these, he stated: "Both patients died promptly, one on the operating table and the other a few hours subsequently."

Four proved cases of active tuberculous pericarditis cured or markedly improved by pericardiectomy [5] form the basis of this report. They have led to certain conclusions at variance with those just expressed. The modifying influence of the availability of streptomycin and other antibiotics on previous conceptions of treatment is conceded as being of considerable importance in a new approach to the problem. In 2 cases the unique opportunity was presented of observing the illnesses in a government hospital continuously for a number of months from the period of effusion to the development of disabling compression by the contracting pericardium. The striking features common to all 4 patients at the time of operation were, first, the advanced state of the

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disease as evidenced by the ascites and the pleural effusions and, second, the relentless and progressive course of the disease as exemplified by the slowly increasing disability imposed by cardiac compression. Clinical, roentgenographic and electrocardiographic evidence in the first 2 cases indicated that this compression was first produced by a pericardial effusion which then subsided only to be followed promptly by the development of compression due to gradual contraction of the fibrous pericardium.

The prolonged course of the disease before operation in these 2 cases, nine months in case 1 and eleven months in case 2, at once raises the question whether the decompression operation of pericardiectomy should have been performed at an earlier date. In retrospect the answer is unequivocally in the affirmative. From a critical review of the cases it would appear that operation in case 1 could have been performed with profit and safety in November or December 1947 instead of in May 1948. Three weeks after the patient's admission, despite general improvement, the paradoxical pulse was still present, and thereafter cardiac impairment was progressive, as disclosed by increasing dyspnea, peripheral edema, tightness in the chest and ultimate pleural and abdominal effusions. Operation in November or December would have obviated a six months' delay in securing release from the constricting pericardium, and much of the patient's disability could have been avoided.

Similarly, in case 2 the patient gave unequivocal evidence of a pericardial effusion with signs of cardiac compression two months after admission to the hospital. In retrospect this was the auspicious moment for operation rather than eight months later after a prolonged period of increasing ascites and persistent right hydrothorax requiring seven aspirations for a total of 7,550 cc. of fluid. At operation a large intrapericardial pocket of tuberculous pus from which a positive culture was obtained was a factor in the cardiac compression. Primary healing and apparently complete cure followed a radical pericardiectomy.

In case 3 an opportunity for more radical treatment was presented in May 1948, at a time of only moderate abdominal effusion, but the patient's own intransigence precluded such a decision at that time, since he left the hospital against advice. More prolonged study and observation at that time would conceivably have led to the diagnosis of cardiac compression, which in the presence of a strongly positive tuberculin reaction would probably have been ascribed to a tuberculous pericarditis. This, with the evidence of compression, should have led to operation at that date. The patient, however, disappeared and did not reappear until September, when he was completely incapacitated from the mechanical effects of the disease and required an emergency abdom-

inal paracentesis to relieve his symptoms. Operation, however, was not performed until December, and again valuable time was lost in the gradual progression of the disease.

In case 4 the period between the development of unequivocal symptoms of cardiac compression and the subsequent operation of radical pericardiectomy for their relief was much shorter, but a month or two could have been saved, which undoubtedly would have been of great advantage in reducing the extent of myocardial damage and in shortening the length of a prolonged and troublesome convalescence.

Emboldened by these experiences, a working rule is presented which suggests that the moment a diagnosis of cardiac compression can be made, an operation for cardiac decompression is indicated, regardless of whether this compression is noted in a stage of pericardial effusion or in a stage of pericardial contraction. This would provide early liberation of the heart from compression, thus correcting the adverse mechanical effects of the disease and permitting a more efficient combating of the inflammatory component. Technically such excision can be performed in the presence of a pericardial effusion with considerably greater ease than is possible at a later stage, when the pericardium and epicardium have become inextricably merged. At this earlier stage there also would undoubtedly be a greatly reduced involvement of the myocardium, which at the later operation is often found far advanced, as in cases 2 and 4.

Heretofore, patients with pericardial effusion, presumably due to tuberculosis, have been treated medically with prolonged rest in bed, with the expectation that the effusion would be reabsorbed, as indeed it was in cases 1 and 2. In both of these there was definite recession in the size of the cardiac outline after a month's rest in bed, only to be followed promptly by compression due to contracture of inflamed and thickened pericardium. However, should circumstances indicate that such improvement is not taking place, that a pericardial effusion with a high temperature persists and that the patient remains in a precarious condition, largely the effect of compression due to fluid, operation should be considered at once. If performed on an extremely ill patient, the operation might be undertaken in two stages, consisting of removal of the sixth left costal cartilage for evacuation of the pericardial fluid, followed ten to twenty days later by the usual midsternal incision and radical pericardiectomy. The first operation might include the introduction of a drain into the pericardial space, which should escape from the chest through a separate laterally placed stab wound, thus permitting complete closure of the first incision and also permitting at the second operation the use of a centrally placed incision independent of both the first incision and the drainage tract. The usual adverse effects of a drain leading from the skin surface into the pericardium would be

obviated during the brief period between operations by streptomycin and penicillin therapy. It would be expected that sufficient improvement would occur after the evacuation of the tuberculous effusion to make the more prolonged and more hazardous but imperative radical pericardiectomy a safer procedure.

At the present time it is axiomatic, of course, that for any patient suspected of having tuberculous pericarditis the administration of streptomycin would be part of the preoperative and postoperative treatment, as in cases 1 to 4. Optimum nutrition is strongly stressed as well, with particular reference to supplementary vitamins and fresh citrus juices as a source of vitamin C. It is becoming increasingly recognized, as was stressed originally in 1937,[6] that the proper functioning of the endocrine system is dependent on adequate nutrition, primarily through the administration of multiple vitamins. Moreover, the elaboration of antibodies against infection is considered by some to be dependent on the presence of adequate vitamins. Hence the great need of fortifying the endocrine system with supplementary vitamins[7] before the ordeal of operation, a precaution that should be observed with every operation of whatever magnitude but particularly with the operation for tuberculous pericarditis.

It is confidently predicted that in most cases of tuberculous pericarditis operation can be performed earlier than has heretofore been believed and that much valuable time, and even life itself, will be saved by so doing.

SUMMARY

Tuberculous pericarditis is characterized by a prolonged course exhibiting in the acute stage chills, sweats, fever, rapid pulse, dyspnea, increased sedimentation rate, leukocytosis, anemia, pericardial friction rub and pericardial effusion sufficient at times to produce compression of the heart and the superior and inferior vena cava as shown by increased venous pressure, by absent ventricular pulsations on fluoroscopy and by a reduced voltage in the QRS complex and inverted T waves in the electrocardiogram. Such effusion may persist, or it may subside as shown by a reduction in the size of the cardiac shadow. In 2 cases this disappearance of pericardial effusion took place within three weeks after complete rest in bed was enforced, only to be followed promptly by signs of cardiac compression due to contracture of the inflamed and thickened pericardium. It is suggested that the insidiously and relentlessly progressive character of tuberculous pericarditis

6. Holman, E.: Preoperative and Postoperative Care, editorial, Surgery **1**:637, 1937.

7. Holman, E.: Vitamin and Protein Factors in Preoperative and Postoperative Care of the Surgical Patient, Surg., Gynec & Obst. **70**:261, 1940.

demands the performance of operation at a much earlier stage than has heretofore been practiced, and that pericardiectomy should be considered at the time of pericardial effusion, particularly if evidence of compression of the heart and the superior and inferior vena cava is present. It is strongly urged that when the diagnosis of cardiac compression can be made clinically, either in the stage of pericardial effusion or in the stage of pericardial contracture, there is great need of prompt cardiac decompression. In a very ill patient with pericardial effusion such decompression might be best effected by removal of the left sixth costal cartilage for evacuation and drainage of the pericardium, followed at a second stage ten to twenty days later by median sternotomy and radical pericardiectomy. In these circumstances, despite the improvement following the first operation, the second operation of pericardiectomy should be performed without fail.

Four patients with proved tuberculosis of the pericardium, active at the time of operation as indicated by positive cultures of tubercle bacilli in 3 and by the demonstration of tubercle bacilli in the tissues in the fourth, were treated by means of radical pericardiectomy. The result was apparent cure in 3 and progressive improvement in 1. All operative areas healed per primam, despite the presence at operation of active tubercle bacilli in the diseased pericardium. The beneficent influence of streptomycin and penicillin on the results is freely conceded.

DISCUSSION

Dr. Stuart W. Harrington, Rochester, Minn.: I wish to compliment Dr. Holman on his excellent presentation and the admirable demonstration of the subject by the use of motion pictures. I am pleased that he has emphasized the importance of the removal of the epicardium as well as of the pericardium. We have found that the epicardium can be removed more adequately if it is left attached to the outer layer of the pericardium, and I also believe that it is important to leave a flap of the pericardium attached to the myocardium which can be utilized in controlling hemorrhage from the coronary vessels or in repairing an injury to the myocardium if it inadvertently occurs.

We have not been as much impressed as Dr. Holman has with the importance of removing the pericardium from around the inferior vena cava, and in many instances I have found that there has been little obstruction to the vena caval vessels. I do think it is important to remove the pericardium and epicardium from the ventricles, particularly at the apex of the heart, as well as to separate the ventricle from the diaphragm, to remove as much as possible the pericardium from the auricles and to do an epicardiolysis in that portion of the epicardium which may be difficult to excise from the auricles. In some instances it may be advisable to leave segments of the adherent pericardium and epicardium over the coronary vessels when the scar is firmly fixed to these vessels in order to avoid injury to them. In some instances the calcified scar extends into the myocardial muscle, and during its removal the myocardium may be injured. In most of these instances it can be sutured satisfactorily, but if it is markedly degenerated, it is well to preserve a flap of the pericardium to suture over it at the point of repair.

One of the most important factors which influence the completeness of the recovery of the patients is the amount of myocardial degeneration which has taken place before the operation. This factor emphasizes the importance of early operation.

Although this disease is essentially one which involves the pericardium and epicardium and in which the contracting scar causes an atrophy of the myocardium, the atrophy will ultimately become a degeneration of the myocardium if the constricting scar is not removed. Another important factor in these cases is not only the risk of operation but the degree of recovery and the amount of liver damage due to inflow stasis which has taken place. Dr. Barnes and I have been interested in the hepatitis in these cases, and we believe that many of the gastric symptoms which the patients present are due to the liver damage. The regeneration of the liver following operation is often slow. In some instances in which there has been marked retention of dye before operation it has taken as long as two or three years before the hepatic test revealed no retention.

Dr. Holman has stressed the importance of complete removal of the constricting scar, which is the most important operative consideration. The rapidity and completeness with which recovery occurs depend on the amount of myocardial atrophy and hepatic damage which has already taken place before the operation. Improvement may be noticed soon after operation but often proceeds slowly and progressively, and complete recovery may not occur for many months or even years. This is dependent to some extent on the age of the patient as well as the duration of the disease before the operation.

Dr. Emile Holman: Obviously, an adherent pericardium is harmful not because it is adherent but because it contracts. It is our contention that this contraction first affects the easily compressible portions of the heart and the great vessels and only subsequently the ventricles themselves. I feel that the calcification which is occasionally seen is unimportant if it is limited to a single area of the heart or of the pericardium, but when it involves the entire circumference of the heart and begins to contract, then it has the effect of constricting the heart in a vise.

SPLENECTOMY FOR TRAUMATIC RUPTURE WITH INTRA-ABDOMINAL HEMORRHAGE

Report of One Hundred and One Cases

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LOS ANGELES

INTRA-ABDOMINAL hemorrhage is the immediate and most urgent indication for splenectomy in cases of traumatic rupture of the spleen. The diagnosis of traumatic rupture of the spleen likewise depends on the presence of the various clinical signs and symptoms produced by intra-abdominal hemorrhage, as there are no known laboratory or investigative procedures that can be used directly on the spleen. Hemorrhage following traumatic rupture of the spleen can be divided clinically into the immediate and delayed types, depending on the lapse of time between the accident initiating the trauma and the development of symptoms of internal bleeding. Trauma to the spleen without intra-abdominal hemorrhage occurs more frequently than one would suspect, but as patients with this condition do not come to surgery the number of cases cannot be accurately estimated. Immediate abdominal hemorrhage from the spleen is not infrequently difficult to diagnose early, as patients suffering from this have usually been in a serious accident, have sustained multiple injuries and are in a state of shock on their admission to the hospital. The presence of intra-abdominal hemorrhage contributes immeasurably to the prolongation of the state of shock, while the degree of shock masks the clinical picture of hemorrhage. In cases in which there is delayed hemorrhage there is a latent period between the time of the accident and the time the bleeding into the abdomen begins, during which the patient may be symptom free or exhibit symptoms of a vague and indefinite character. Failure of the physician to evaluate the abdominal trauma sustained in supposedly minor accidents and the fact that the patient may forget the incident of trauma will frequently lead to an erroneous diagnosis. It is the purpose of this paper to present an analysis of 101 cases in which rupture of the spleen followed trauma to the abdomen, intra-abdominal hemorrhage occurred and the spleen was removed surgically.

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INCIDENCE

In the ten year period 1936 to 1946 one hundred and seventy-eight splenectomies were performed for various conditions at the Los Angeles County General Hospital. In 101 cases there was a history of trauma as the inciting cause, the spleen was ruptured and intra-abdominal hemorrhage was the indication for surgical intervention. It is likely that many patients with traumatic splenic rupture never reach the operating room, as multiple injuries and shock rapidly produce a fatal termination. The largest group of patients were from 1 to 20 years of age (table 1), the youngest being 3 and the oldest 74. Ninety-one per cent of the patients admitted to the hospital were between the ages of 1 and 50. These are the years of greater physical activity, when accidents are commoner and abdominal trauma more likely to occur. With increasing congestion and

TABLE 1.—*Age Incidence*

Years	10	20	30	40	50	60	70	80	
Cases	32	27	24	9	7	1	2	..	Total 101

Youngest—3 yr. old boy in automobile accident, fractured wrist
Oldest—75 yr. old man, hit with hammer

TABLE 2.—*Type of Accident*

	Automobile, Passenger	Automobile, Pedestrian	Fall	Gunshot Wound	Suicide	Stab Wound	Fight	Motorcycle Accident	Bicycle Accident
Recovered	25	15	10	9	6	2	6	1	3
Died	4	6	..	5	2	1	1	1	..
Total	29	21	10	14	8	3	7	2	3

the use of the motor car the age incidence of traumatic rupture of the spleen is increasing and a greater number of patients in the later decades are being treated for this condition, when previously the highest incidence occurred among more youthful persons.

TYPE OF ACCIDENT

A detailed history of the accident in which the trauma was sustained plays some role in the diagnosis of a traumatic rupture of the spleen. Accidents in which the patient receives multiple injuries, regardless of the type and location, are serious accidents, and the possibility of a ruptured spleen must be suspected although no history of direct violence is obtained. It has been shown that direct violence to the abdomen as well as contrecoup force can produce a ruptured spleen. Approximately half of the patients coming to splenectomy because of internal hemorrhage were in accidents in which the motor car was the instigating force (table 2). Patients injured in this type of accident presented the greatest

number of injuries, and shock was the most significant early finding. Although a detailed history is difficult to obtain from some patients on their admission to the hospital, the accident may seem trivial and subsequent conversation will bring out a history of striking the abdomen against the steering wheel, dashboard or back of a seat. Gunshot wounds of the abdomen, either deliberate or accidental, were responsible for the second largest group of ruptured spleens. Patients with these received the most efficient attention and were operated on quickly after their admission to the hospital, as the violence was evident and surgical exploration obviously required to determine the extent of the injuries. Because of multiple visceral perforations in this group, the mortality rate was the highest. Direct trauma to the abdomen during a fight or a fall constituted the type of accident in 16 per cent of the patients received; the visceral injury was usually single, involving only the spleen, or occasionally one or two ribs on the same side, and the intra-abdominal hemorrhage was of the delayed type, with a latent period between the time of the accident and the appearance of the symptoms. Bicycle and motorcycle accidents accounted for several cases, and stab

TABLE 3.—*Duration of Injury*

Time	24 Hr.	2 Days	3 Days	4 Days	5 Days	7 Days	8 Days	9 Days	14 Days	21 Days
Cases.....	74	14	2	3	1	2	1	1	1	1

wounds were the cause of injury in 2 cases. Direct violence to the abdomen was the inciting cause in the majority of cases, regardless of the type of accident, and when this history is not obtained it is sometimes obvious that the patient may have forgotten the incident or it may be deliberately withheld from the physician. There is some correlation between the type of accident and the age incidence, as the activities of youth and early adolescence are more likely to lead to the employment of the aforementioned accident mechanism. Minor accidents, such as a fall in the bathtub or against a curbstone or step, will produce a fractured spleen, especially if the left side is struck, and the patient will attach little importance to the injury at the time of the accident.

DURATION OF INJURY

Fourteen days is probably sufficient time to observe a suspected case of splenic rupture, and after this time a comparatively safe period is reached, as all the patients included in this report with one exception were operated on within this period. The one exception was a patient operated on twenty-one days after the trauma, and there are several patients reported in the literature who were operated on on the thirtieth day. The spleen was removed to control abdominal hemorrhage in 73.2 per cent of the cases (table 3) within twenty-four hours from the time

of injury. The second largest group, 14 patients, were treated within two days after injury, and some of these did not have true delayed hemorrhage, as shock will influence and delay intra-abdominal hemorrhage for a considerable period. The presence of unconsciousness in patients with head injuries delays the diagnosis; shock and other factors were noted in some of the cases in the second group. A few were typical instances of delayed rupture with an asymptomatic period between the time of injury and hospitalization. The remaining 13 cases were true examples of delayed hemorrhage, displaying a typical "latent period" as described by Baudet, and coming to surgery on the third, fourth, fifth, seventh, eighth, ninth, fourteenth and twenty-first day after the trauma.

TABLE 4.—*Immediate Hemorrhage in Patients Operated on Within 24 Hours*

	Number of Cases
Automobile accident, passenger	22
Automobile accident, pedestrian	17
Gunshot wound	14
Suicide	8
Fall	3
Fight	2
Stab wound	3
Motorcycle accident	2
Bicycle accident	3
Total	74

SPLENECTOMY FOR IMMEDIATE HEMORRHAGE

Seventy-four patients underwent splenectomy within twenty-four hours of the trauma. In the majority of the cases the accidents were of a serious nature, requiring immediate hospitalization, and the patients arrived unconscious or in various degrees of shock (table 4). The presence of shock was the most difficult problem in the evaluation and treatment of the injuries, and the treatment of multiple injuries added to the already numerous problems of handling these patients. In all of them intra-abdominal hemorrhage was immediate and the rapidity of bleeding influenced only by the degree of shock present, and early diagnosis was found to be most difficult. The possibility of a ruptured spleen with hemorrhage, masked or delayed by shock, should be a mental reservation in the treatment of patients with multiple injuries. The use of diagnostic abdominal paracentesis in the difficult cases was found to be the most valuable single procedure. Abdominal tap was used in 12 cases in which the diagnosis was doubtful for various reasons; in 11 cases it gave positive results and the diagnosis was confirmed, and in 1 case a false negative result was obtained. It has been my experience

when paracentesis is deemed advisable that multiple taps must be made, as a single tap may be misleading. This diagnostic procedure seems a valuable improvement over the method of watching the patient and relying on the repeated blood counts and the blood pressure reading to lead to a diagnosis. Wright and Prigot [1] have likewise found abdominal paracentesis a valuable aid in making an early diagnosis.

Repeated blood cell counts and hemoglobin determinations, while valuable and necessary in the treatment of the patient, did not aid materially in arriving at an early diagnosis of traumatic spleen. The white blood cell count was frequently increased and in the presence of compound fractures, chest wounds and soft tissue wounds could not be relied on as indicative of hemorrhage. Repeated red blood cell counts were misleading as in many cases the shock was treated with transfusions and the patient's count was increased to within the normal range. Hemorrhage did not become evident in some of the cases until the degree of shock became minimal, and the abrupt onset of hemorrhage would frequently throw the patient back into shock and collapse. Hemoglobin determinations were of little value, as might be expected, since sudden hemorrhage allowed insufficient time for a change in the hemoglobin of the circulating red cells. Considerable blood can be lost quickly from a lacerated wound of the scalp, and hemorrhage inside the abdomen would continue undiscovered if one were to rely on blood counts as an index of the patient's condition. Blood counts done on the patients several days after surgical intervention were more typical of changes produced by hemorrhage than those made before. Blood pressure readings were consistently low, many patients having systolic levels of 100 mm. or below on their admission to the hospital. As both shock and hemorrhage will produce a fall in blood pressure and as both of these conditions may be present in the same patient, it was found to be more satisfactory to use blood pressure determinations to measure the recovery from shock and not to rely on them as an indication of intra-abdominal bleeding. In all the cases in this group the white blood cell count was increased.

SPLENECTOMY FOR DELAYED HEMORRHAGE

Delayed intra-abdominal hemorrhage from the injured spleen occurred in 26 per cent of the patients treated for traumatic rupture (table 5). The injury in this group was usually confined to the spleen. Hemorrhage was a prominent and early feature of the clinical picture, and the mortality was the lowest. In many instances there was a latent period from the time of injury until the onset of the symptoms. Occasionally the symptoms were minor in character, the patient was not

1. Wright, L. T., and Prigot, A.: Traumatic Subcutaneous Rupture of the Normal Spleen, Arch. Surg. **39**:551 (Oct.) 1939.

disabled and he continued at home without seeing a physician, only to have a sudden onset of symptoms later. In a few cases one or more fractured ribs obscured the real injury or the symptoms were related to the chest or the gastrointestinal tract and the true nature of the injury was not suspected until a sudden large hemorrhage sent the patient into collapse. Elicitation of a history of trauma from the patient was a most important aid in arriving at a diagnosis of intra-abdominal hemorrhage from a ruptured spleen. If this history of trauma was not obtained from the patient, the diagnosis was frequently not made before operation. In many cases a history of trauma was obtained from the patient only after close questioning during the period of recovery, as was true in the case of a 17 year old boy who reluctantly disclosed to the intern that he had received a severe beating at the hands of his father five days previous to his admission to the hospital. It has been my observation that in all

TABLE 5.—*Delayed Hemorrhage in Patients Operated on Within 2 to 21 Days*

	Number of Cases
Accident, passenger	7
Accident, pedestrian	4
Fall	7
Fight	5
No history	4
Total	27

cases of delayed intra-abdominal hemorrhage following rupture of a normal spleen there is always a history of trauma, if the time and effort are expended to get it from the patient.

In patients with delayed hemorrhage the condition was frequently mistaken for other visceral lesions producing symptoms of an acute condition within the abdomen. The red blood cell count and hemoglobin content were consistently low in this group of patients and gave a more accurate picture of the abdominal conditions than those in patients with immediate hemorrhage and shock. The lowest counts recorded were 2,100,000 red cells and a 26 per cent hemoglobin value in a patient who had been struck in the abdomen, over the spleen, four days previously. Blood pressure readings were not consistently lowered in cases of delayed hemorrhage and did not consistently fall as the rate of the intra-abdominal bleeding increased. Repeated blood counts gave a more accurate clinical picture in cases of delayed hemorrhage, while the blood pressure determinations followed variations in the degree of shock more consistently and did not fall with the amount of abdominal bleeding.

SIGNS AND SYMPTOMS

Traumatic rupture of the spleen with hemorrhage produced a certain symptom pattern, and certain signs developed which could be used in diagnosing the underlying pathologic changes. This pattern, while modified by the presence of shock and multiple injuries, was usually found to be present provided the examiner was diligent in his search for it. Obviously this does not hold true when the injury is an abdominal gunshot or a stab wound, and in these instances the diagnosis is of secondary importance. In 34 per cent of the cases in which the trauma was not due to gunshot or stab wounds a triad of abdominal rigidity, abdominal tenderness and pain in the shoulder (Kehr's sign) was present. The abdominal rigidity was variable, ranging from a generalized rigidity as seen in cases of acute perforated ulcer to rigidity localized to the left upper quadrant and radiating into the back. Abdominal tenderness was likewise variable, but more commonly was present in the left upper quadrant and frequently accentuated on deep breathing. The

TABLE 6.—*Signs and Symptoms*

	Number	Percentage
Abdominal pain	47	46.5
Shoulder pain (Kehr's sign)	29	28.7
Chest pain	15	14.3
Abdominal tenderness	48	47.6
Abdominal rigidity	42	41.0
Dulness in flanks (Ballance's sign)	10	5.9

presence of pain in the shoulder and neck, or a positive Kehr sign, was in direct proportion to the number of patients who were questioned concerning this sign. The patient's complaints are focused on the abdomen, and he does not volunteer information about pain in the shoulder, but the answer is invariably in the affirmative when the question is asked directly. Painful respiration was one of the complaints in 18 cases, and dulness in the flanks, or Ballance's sign, was noted in 10 cases. The presence of abdominal rigidity and tenderness and a positive Kehr sign constitute a symptom triad that can be used fairly accurately to diagnose a ruptured spleen in cases of abdominal injury. The 27 patients with delayed hemorrhage from a ruptured spleen were usually free of symptoms during a certain latent period. The onset of symptoms following this latent period were abrupt and ushered in with fainting or collapse, similar to those in a woman with rupture in an ectopic pregnancy. These cases represent true instances of delayed rupture of the spleen following trauma. In 9 cases of delayed hemorrhage the patient had abdominal symptoms of a vague and indefinite character, and they were found to have tamponade with intermittent intra-abdominal hemorrhages at operation.

PATHOLOGIC CHANGES IN SURGICAL SPECIMEN

The gross findings in the surgical specimen as reported by the pathologists have been correlated with respect to immediate or delayed hemorrhage following trauma to the spleen. In all the specimens represented in this report the splenic tissue was reported normal by the pathologists. The only microscopic changes reported were those incident to trauma and hemorrhage, either intracapsular or extracapsular. This fits in with the contention that in all cases of delayed rupture of the spleen there is a history of trauma in the background and that spontaneous hemorrhage never occurs in the normal spleen. Twenty-one per cent of the spleens removed in cases in which hemorrhage was delayed were described as showing areas of parenchymal hemorrhage and hematoma formation, elevation of the capsule from the splenic tissue and multiple breaks in the capsule (table 7). This parallels the findings

TABLE 7.—*Gross Pathologic Changes*

Splenic Injury	Number of Cases	Hemorrhage	
		Immediate	Delayed
Single laceration	15	13	2
Multiple or stellate lacerations	22	20	2
Upper pole injuries	17	14	3
Lower pole injuries	7	5	2
Hilar or pedicle laceration	5	5	..
Bisected	10	10	..
Macerated	9	4	5
Splenic tumor with rupture	16	3	13
Totals	101	74	27

described by McIndoe[2] and other writers, who recognized that the initial bleeding is intrasplenic or intracapsular and that the intra-abdominal hemorrhage which is delayed occurs when the capsule breaks. In 9 patients the spleen was described as being macerated, 4 of whom had immediate hemorrhage and 5 delayed hemorrhage. It would seem logical to assume that in all cases in which the spleen is macerated the hemorrhage is immediate, but in 5 cases the intra-abdominal hemorrhage was delayed, as the initial lesions were multiple parenchymal lacerations with hemorrhage, tumor formation and then explosion through the capsule. These five specimens probably represent delayed rupture of the spleen. The spleen was bisected or torn in half in 10 cases, and the intra-abdominal bleeding was immediate. A single laceration of the spleen, usually incomplete bisection of the organ, produced immediate signs and symptoms of abdominal hemorrhage except

2. McIndoe, A. H.: Delayed Hæmorrhage Following Traumatic Rupture of the Spleen, Brit. J. Surg. **20**:249 (Oct.) 1932.

in 2 cases. In these cases tamponade was effected and bleeding stopped temporarily by a blood clot in one and by the tail of the greater omentum in the other. Hilar or pedicle lacerations produced immediate and severe bleeding in all cases and the largest hemorrhage, approximately 3,500 cc. of blood, reported at the time of operation. Damage to the upper and lower poles of the spleen was reported in 24 and 19 cases respectively. Multiple or stellate lacerations of the spleen were found in 22 cases, and the abdominal hemorrhage was immediate in 20 and delayed in 2. In these 2 instances the lesions were produced by a single bullet hole in the spleen filled with blood clot and radiating stellate lacerations and the hemorrhage was delayed. In three of the spleens with lacerations of the upper pole and two with lacerations of the lower pole the hemorrhage was delayed by tamponade of a different type. At the time of surgical intervention the ruptured spleen and a quantity of blood were found walled off between the stomach and diaphragm and the colon and greater omentum. It was in this type of case that a false negative result of abdominal paracentesis was obtained. In an analysis of the 101 specimens, two mechanisms become apparent as influencing the rate of intra-abdominal bleeding and the onset of the signs and symptoms of a ruptured spleen. In delayed rupture there is initially a tear in the parenchyma, with parenchymal or intracapsular bleeding. This bleeding may continue until such time as the capsule gives way, as a result of either the increased intracapsular pressure or a break caused by trauma from coughing or sneezing or straining at stool. In 1 of the cases studied delayed hemorrhage occurred after a severe vomiting spell. These are true instances of delayed rupture of the spleen. Hemorrhage may also be of the delayed type provided the damage to the spleen consists of one or several lacerations in the upper or lower pole of the spleen and tamponade occurs. This tamponade may consist of a plug of clotted blood or omentum, or there may be a collection of old blood and clot walled off between the stomach, diaphragm, colon and omentum. It must not be forgotten that the presence of shock will influence the rate of intra-abdominal bleeding, and this does not constitute true delayed rupture of the spleen. I do not believe that spontaneous rupture of the normal spleen occurs. Zuckerman and Jacobi [3] stated the belief that there is a failure in the development of the normal ligamentous attachments of the spleen with distention and engorgement following meals and possible torsion of the pedicle, followed by spontaneous rupture of the capsule. The experience in this group of cases was that if the rupture occurred in a normal spleen one could always elicit a history to explain it.

3. Zuckerman, I. C., and Jacobi, M.: Spontaneous Rupture of the Normal Spleen, Arch. Surg. **34**:917 (May) 1937.

Immediate intra-abdominal hemorrhage occurred in cases in which the splenic tissue was macerated or in which the organ was broken in half or bisected or when the lacerations were in the hilar region. The presence of large vessels in the hilus usually predisposes to immediate and severe hemorrhage. A common type of injury to the spleen is a single laceration on the diaphragmatic surface, usually deep but without separation of the two portions of the organ and most frequently in the long axis of the spleen. A close study of all the surgical specimens, both grossly and microscopically, in terms of the clinical findings in the case and the severity and rapidity of the hemorrhage leads to certain conclusions. Delayed rupture occurs in cases in which the laceration is in the parenchyma without a break in the capsule. The hemorrhage is then intracapsular or intrasplenic, with single or multiple hematomas, and the spleen enlarges and may form a tumor mass. Rupture of the capsule, caused by either increased pressure from within or trauma from without, allows the bleeding to increase, and signs of intra-abdominal hemorrhage are produced. At operation these specimens will show all the various types of lacerations found in immediate splenic rupture, but microscopically the capsule will show evidence of having been stripped from the parenchyma by intracapsular hemorrhage. Single or multiple lacerations through the capsule of the spleen and into the parenchyma produced immediate abdominal hemorrhage, unless it is temporarily stopped by shock or controlled by tamponade. Tamponade may occur from a clot of blood with some organization and fixation, or the omentum may act as a plug to the bleeding. Hemorrhage may be delayed by the walling-off action of the viscera, diaphragm and omentum. In 73 per cent of the cases in which trauma produces injury to the spleen the intra-abdominal hemorrhage will be immediate and severe and splenectomy must be done to save life.

SURGICAL TREATMENT

There are two important points to be made in discussing splenectomy for traumatic rupture. The first to be emphasized is the use of the left rectus incision. Many of the patients were operated on through a right rectus incision because of a mistaken diagnosis, while in other cases this incision was used because of the presence of other abdominal lesions or for purposes of a thorough exploration. The spleen is normal in size or only slightly enlarged, and there are no adhesions to the diaphragm or other complications to increase the technical difficulties of operation. Delivery is rapid, hemorrhage easily controlled through the splenic pedicle and the operation less time consuming. In a few instances the operator used a "T" extension in his incision, an addition which I do not believe necessary. The second point of importance is the location of the large vessels in the hilus of the spleen. These ves-

sels are more accessible and can be exposed more readily and clamped singly from the posterior aspect of the pedicle. Anteriorly, there are the lienogastric and the lienorenal ligaments making up the pedicle, while posteriorly the vessels are on the surface. For these reasons, when the spleen is delivered through the incision the organ is rotated over, toward the midline, exposing the vessels on the undersurface of the pedicle. None of the surgical complications that one encounters in operations for splenomegaly, e. g., Banti's disease, was seen in these cases.

MORTALITY RATE

The mortality rate in this series of 101 cases was 16.8 per cent. The greatest number of fatalities was in the patients with multiple injuries, while there were 2 deaths in the group with single injuries. The cause of death in the 2 cases was listed as hypertension and shock in 1 and generalized peritonitis of unknown cause in the other (table 8). The

TABLE 8.—*Mortality Rate (16.8 Per Cent)*

Type of Accident	Multiple Injury	Single Injury	No. Deaths
Gunshot and suicide	Multiple Perforations	.....	8
Automobile, passenger	Fractures	.....	3
Automobile, pedestrian	Fractures (2)	Shock (2)	4
Motorcycle	Skull fracture	.....	1
Fight	Tear in jejunum	.....	1
Total			17

presence of multiple injuries was the immediate cause of death in the majority of patients, especially when gunshot wounds of the abdomen were present. One patient died from a single perforation in the jejunum after a blow to the abdomen, which was overlooked at the time of operation. Careful exploration of the abdominal viscera must be done in all cases, regardless of the condition of the patient, as it has been my experience that blood transfusion is far more beneficial to the patient in the operating room with the spleen exposed and hemorrhage controlled than in the ward before operation. Undoubtedly there were some patients admitted to the hospital with traumatic rupture of the spleen and multiple associated injuries who died before reaching the operating room. These cannot be included in the mortality figures. It requires a fine sense of surgical judgment in treating these patients with multiple injuries to determine when the state of shock is improving, when intra-abdominal hemorrhage is increasing and when operation should be performed. The largest number of deaths was from multiple visceral perforations following gunshot wounds of the chest and abdomen. Patients injured in motor car accidents form the second largest group in which death occurred.

SUMMARY

The diagnosis of traumatic rupture of the spleen depends on the presence of intra-abdominal hemorrhage. This hemorrhage may occur immediately after the injury, or it may be delayed for one to fourteen days. Patients with immediate hemorrhage also have the largest number of multiple associated injuries and are hospitalized in varying stages of shock, which mask the clinical signs of hemorrhage. Diagnostic abdominal paracentesis was a great help in making a diagnosis in acutely ill patients. In cases of delayed hemorrhage from traumatic rupture of the spleen, a history of trauma cannot always be obtained from the patient on his admission to the hospital and the acute abdominal condition may be mistakenly thought to be due to other visceral lesions. The triad of abdominal tenderness, rigidity and pain in the shoulder was noted so frequently in the series reported on here that it is believed it can be used to make a diagnosis of a ruptured spleen in a large percentage of cases. A critical examination of the surgical specimens, grossly and microscopically, revealed evidence to indicate that delayed hemorrhage is not always due to delayed rupture of the spleen. In cases of delayed rupture the capsule of the spleen is intact after trauma and the lesion and bleeding are in the parenchyma, with later capsular rupture and bleeding into the abdomen. The spleen may be ruptured at the time of injury and the intra-abdominal hemorrhage delayed by tamponade. Lacerations and ruptures in the spleen involving the capsule result in immediate hemorrhage into the abdomen in the majority of cases, influenced only by the degree of shock in the patient. Bold delivery of the spleen through a left rectus incision and exposure of the vessels in the pedicle by rotation of the spleen toward the midline with the diaphragmatic surface down were found to be the best, safest and quickest method of splenectomy. The highest mortality rate was in patients with gunshot wounds of the abdomen.

DISCUSSION

Dr. William Requarth, Chicago: In a ten year period at the Cook County Hospital splenectomy has been performed on 22 patients with rupture of the spleen due to blunt violence. These patients were studied to determine the cause of errors in diagnosis. Delay in diagnosis was frequently caused by failure to recognize that variations in the pathologic process produced variations in clinical signs. As an aid in early diagnosis, rupture of the spleen can be classified as three types: (*a*) classic rupture with massive hemorrhage and abdominal pain and tenderness due to peritoneal irritation by action of blood, (*b*) rupture of parenchyma with subcapsular or retroperitoneal hematoma with no blood in peritoneal cavity and consequently little pain and tenderness and (*c*) delayed rupture of the spleen. Diagnosis is made easier if the surgeon keeps in mind these variations which can alter the clinical symptoms to a marked degree.

The presence of fractured ribs on the left masked splenic injury in 6 cases. Rupture of the spleen should be ruled out in all patients with fractured left ribs.

The roentgenologic findings of an opacity in the left upper quadrant and limitation of motion of the diaphragm helped the diagnosis in 65 per cent of the cases. About one fourth of the patients were thrown against the steering wheel in an automobile accident.

Our series was small; we did not include stab wounds or gunshots. The mortality was 9.5 per cent. Dr. Chester Guy reported 20 cases of rupture of the spleen in the ten years preceding this study, with a mortality of 40 per cent. The availability of blood in recent years is probably the chief factor in improving the mortality rate.

Dr. Ralph V. Byrne: In this brief presentation I did not mention roentgenograms of the chest and abdomen. For most of these patients a plain flat plate of the abdomen and a roentgenogram of the chest are made, but the time was too short and the findings were not consistent enough for me to mention it.

ROLE OF STELLATE BLOCK IN VARIOUS INTRACRANIAL PATHOLOGIC STATES

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THE ROLE played by vasospasm in vascular disease is receiving increasing attention from surgeons dealing with peripheral circulatory disturbances. That cerebral vasospasm may be equally important in various intracranial pathologic states is not widely accepted,[1] and as a consequence comparatively little attention has been directed toward an effective means of overcoming such spasm in instances in which it presumably is a causal factor of clinical importance.

It is probable that this lag in interest in cerebral vasopasm stems largely from the earlier physiologic concept that the cerebral circulation is influenced chiefly by extracranial factors such as the systemic blood pressure, the carotid sinus and other reflex mechanisms.[2] It is now generally recognized, however, that in addition to these obviously important extracranial influences there are significant intracranial mechanisms which affect the cerebral circulation. In brief, these are the carbon dioxide and oxygen tension of the arterial blood supplying the brain, the intracranial pressure, direct traumatic stimuli to the cranial vessels, the effect of various drugs such as nicotinic acid and, finally, the influence of cerebral vasoconstrictor and vasodilator nerves.[3]

From the Division of Neurologic Surgery, University of California School of Medicine.

Read at the Fifty-Seventh Annual Meeting of the Western Surgical Association, Santa Barbara, Calif., Dec. 2, 1949.

1. Pickering, G. W.: Transient Cerebral Paralysis in Hypertension and in Cerebral Embolism, with Special Reference to Pathogenesis of Chronic Hypertensive Encephalopathy, J. A. M. A. **137**:423-430 (May 29) 1948.

2. Forbes, H. S., and Wolff, H. G.: Cerebral Circulation: Vasomotor Control of Cerebral Vessels, Arch. Neurol. & Psychiat. **19**:1057-1086 (June) 1928.

3. (*a*) Cobb, S., and Finesinger, J. E.: Cerebral Circulation: Vagal Pathway of Vasodilator Impulses, Arch. Neurol. & Psychiat. **28**:1243-1256 (Dec.) 1932. (*b*) Forbes, H. S., and Cobb, S.: Vasomotor Control of Cerebral Vessels, Brain **61**:221-233 (June) 1938. (*c*) Kety, S. S., and Schmidt, C. F.: Effects of Altered Arterial Tensions of Carbon Dioxide and Oxygen on Cerebral Blood Flow and Cerebral Oxygen Consumption of Normal Young Men, J. Clin. Investigation

It has been determined in the experimental animal that stimulation of the cervical sympathetic trunk produces ipsilateral spasm of pial vessels, which, however, is considerably less than the vasospasm produced in vessels of comparable size by sympathetic stimulation elsewhere in the body.[3b] There have been no direct measurements made of the effect of sympathetic stimulation on the caliber of the vessels within the brain substance, but, experimentally, sympathetic paralysis resulting from cervical sympathectomy has been shown to cause an increase in the size of the ipsilateral intracerebral capillary bed.[4] Thus it seems evident that the cervical sympathetic chain does carry impulses which can influence the caliber of both pial and intracerebral vessels.

It is also probable, although disputed,[1] that cerebral vasospasm may either initiate or contribute to such neurologic disorders as hemiplegia, aphasia and hemianopsia. Realizing this possibility, Leriche and Fontaine[5] first proposed the interruption of the intracranial vascular sympathetic innervation by procaine hydrochloride block of the stellate ganglion in instances in which vasospasm was thought to be present. Others have subsequently been interested in this procedure for the treatment of cerebrovascular accidents,[6] but it has not received the attention that it deserves. We first became interested in this method of treatment for acute cerebrovascular accidents when we observed its use in the following case.

CASE 1.—W. W., a 57 year old lumberman, was admitted to the Franklin Hospital on the service of Dr. Howard A. Brown in October 1947 because of increasing weakness on the left side of four days' duration. Four days prior to

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27:484-492 (July) 1948. (*d*) Kety, S. S.; Shenkin, H. A., and Schmidt, C. F.: Effects of Increased Intracranial Pressure on Cerebral Circulatory Functions in Man, ibid. **27**:493-499 (July) 1948. (*e*) Chorobski, J., and Penfield, W.: Cerebral Vasodilator Nerves and Their Pathway from the Medulla Oblongata, with Observations on Pial and Intracerebral Vascular Plexus, Arch. Neurol. & Psychiat. **28**:1257-1289 (Dec.) 1932. (*f*) Forbes and Wolff:[2]

4. Talbott, J. H.; Wolff, H. G., and Cobb, S.: Cerebral Circulation: Changes in Cerebral Capillary Bed Following Cervical Sympathectomy, Arch. Neurol. & Psychiat. **21**:1102-1106 (May) 1929.

5. Leriche, R., and Fontaine, R.: De l'infiltration stellaire dans les embolies cérébrales, dans les spasmes vasculaires postopératoires de l'encéphale et chez les hémiplégiques, Rev. de chir., Paris **74**:755-758 (Dec.) 1936.

6. (*a*) Volpitto, P. P., and Risteen, W. A.: Use of Stellate Ganglion Block in Cerebral Vascular Occlusions, Anesthesiology **4**:403-408 (July) 1942. (*b*) Gilbert, N. C., and de Takats, G.: Emergency Treatment of Apoplexy, J. A. M. A. **136**:659-665 (March 6) 1948. (*c*) Risteen, W. A., and Volpitto, P. P.: Role of Stellate Ganglion Block in Certain Neurologic Disorders, South. M. J. **39**:431-435 (May) 1946. (*d*) de Pereira, A.: Blocking of the Middle Cervical and Stellate Ganglions with Descending Infiltration Anesthesia, Arch. Surg. **50**:152-165 (March) 1945. (*e*) Mackey, W. A., and Scott, L. D. W.: Treatment of Apoplexy by Infiltration of Stellate Ganglion with Novocain, Brit. M. J. **2**:1-4 (July 2) 1938.

his entry, on arising from a chair, he suddenly felt faint and noted immediate weakness of his left arm and leg, accompanied with a dull left frontal headache. He was able to walk with a limp and could use his left arm and hand but was clumsy with them. These symptoms persisted without change for two days, when the weakness and lack of control became more pronounced and progressed steadily until the time of his entry to the hospital.

His past history revealed excessive intake of alcohol and that he was a heavy smoker, but it was not otherwise significant.

The pertinent points in the physical examination were a blood pressure of 135 systolic and 95 diastolic, generalized peripheral arteriosclerosis and both generalized and localized narrowing of the retinal vessels, the optic fundi being otherwise normal. There was left hemiparesis, the arm and face being affected more than the leg. He was still able to walk, but with a pronounced limp. Skilful movements of the left hand and fingers were impossible, and the left grip was reduced by 75 per cent, although proximal movements were fairly well performed. The left arm was flaccid, with hypoactive deep reflexes, and the leg was slightly spastic, the tendon reflexes being hyperactive. A Babinski response was present on the left.

Laboratory Data.—The blood and urine were normal. The blood Wassermann and Kolmer tests gave negative reactions. Roentgenograms of the skull showed no abnormality. Lumbar puncture disclosed an initial pressure of 130 mm. of water. The cerebrospinal fluid was clear and contained no cells. The Pandy reaction was negative; the total protein was 33 mg. per hundred cubic centimeters, and the Wassermann reaction and colloidal gold curve were normal.

On the morning after his admission the hemiparesis affecting his left side had become a complete hemiplegia. An injection of 10 cc. of 1 per cent procaine hydrochloride was made into the region of the right stellate ganglion. Within three minutes a Horner syndrome was present on the right, he was able to get out of bed and walk with only a slight limp, facial movements became symmetric, he was able to raise his left arm above his head and his left grip returned to within 75 per cent of normal as measured by the dynamometer. This striking improvement persisted for eight hours, at which time increasing weakness reappeared. This time a stellate block was immediately done on the left, with equally good results even though this was the side opposite to the site of intracranial disease. He was given oral doses of 100 mg. of nicotinic acid every six hours, and daily procaine blocks of the right and left stellate ganglions alternately were carried out for five days. At this time function of the left arm and leg was normal as judged by his gait, muscle testing and subjective symptoms. He was discharged on the seventh day in the hospital and has remained entirely well to date.

The immediate and ultimately sustained improvement following stellate block in this instance was most dramatic and almost certainly was the chief factor in the patient's rapid and complete recovery.

During the ensuing two years a total of 155 patients suffering from acute cerebrovascular accidents have been treated in similar fashion. The results of this form of therapy in the various types of disorders are shown in table 1.

The assay of the effectiveness of any therapeutic measure in such a group of patients is admittedly difficult, since the degree of recovery which may occur in an individual patient without treatment is variable. The results have simply been classified as good in those patients whc

made a complete clinical recovery, fair in those who recovered partially and poor in those who showed no immediate or continued improvement or who died.

We have been reluctant to block the stellate ganglion in patients when the history and physical findings or the presence of blood in the cerebrospinal fluid indicate an acute cerebral hemorrhage, fearing that the bleeding might be augmented and the degree of irreparable brain damage increased. We have therefore preferred to wait until evidence of fresh bleeding (bloody cerebrospinal fluid) has disappeared.

An anterior approach to the region of the stellate ganglion has been used in all instances. The needle is passed between the two heads of the sternomastoid muscle at a point 1 cm. above the clavicle. It is inclined slightly mesially and horizontally until the seventh cervical transverse process is struck. By shifting the point of the needle mesially, one can

TABLE 1.—*Results of Stellate Block for Cerebrovascular Disorders*

Diagnosis *	Number	Result					
		Good	%	Fair	%	Poor	%
Cerebrovascular thrombosis							
Proved by angiography	12	6	50	3	25	3	25
Diagnosed clinically	102	57	56	27	26	18	18
Cerebral embolism	28	15	53	7	25	6	22
Episodic cerebrovascular spasm							
Following angiography	4	4	100	..	..	..	..
Hypertensive encephalopathy	9	9	100	..	..	..	..
Total	155	91	59	37	24	27	17

* We have adhered to the generally accepted criteria and categories for classification of cerebrovascular accidents.[6b]

then feel the junction of the transverse process with the vertebral body. After aspiration to detect the presence of blood or cerebrospinal fluid, 2 to 3 cc. of 1 per cent procaine hydrochloride is then injected. This amount is often sufficient to produce a Horner syndrome, which signalizes a successful injection. Additional procaine is injected if Horner's syndrome is not produced by the initial dose. This method of injection has proved reliable and safe, no untoward effects having been encountered in over 700 injections. The number and frequency of injections have varied depending on the condition of the patient and the result obtained with the initial injection. In many patients one or two injections have sufficed and steady improvement has followed. Other patients have required injection as often as three times daily for several days. With repeated injections, the response usually becomes successively less noticeable. In the past two months we have simplified the procedure for repeated injections by inserting through the needle a small catheter which is left in place and utilized for later instillation of procaine hydrochloride.

Electroencephalographic tracings have been obtained in 35 cases just before the performance of stellate block and repeated as soon as the effect of the block was apparent. When clinical improvement took place, a corresponding improvement usually, but not invariably, occurred in the electroencephalographic tracing (fig. 1). Improvement in grip has been recorded by dynamometer measurements before and after the block.

The effect of stellate ganglion block has been studied in a second group of patients in whom there was no evidence of a cerebrovascular accident but in whom it was hoped that an improvement in cerebral blood supply would be helpful. The following case is cited as an example of this group.

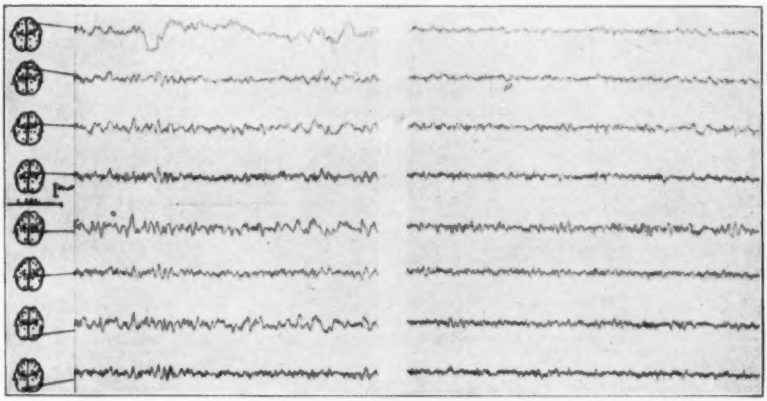

Fig. 1.—C. R., aged 49, had convulsions for thirty-two years. The electroencephalogram on May 9, 1949, showed generalized dysrhythmia. Four days prior to the patient's admission to the hospital, she had weakness of the left leg, which cleared but then recurred after one day, and since that time she had progressive paralysis of the left arm and leg. The electroencephalogram on May 31, 1949, showed gross focal dysrhythmia in right central area and parietal and generalized dysrhythmia. The electroencephalogram pictured here, taken on June 7, 1949, show the tracings before and after left stellate block; the right frontal focus is improved after stellate block.

Case 2.—E. T., a 51 year old house wife, was first seen in 1943 because of proptosis of the left eye. A subtotal removal of a meningioma of the sphenoidal ridge was performed, the patient making an uneventful recovery. She reentered the University of California Hospital in March 1949 because of a gradual recurrence of the proptosis accompanied with the appearance of a mass in the left temporal region. At reoperation recurrent tumor was found to be invading the orbit and extending laterally along the sylvian fissure and inferior frontal convolution. It was densely adherent to the cortex at this point and was removed with difficulty, the cortex being somewhat contused in the process. Complete aphasia and right hemiplegia were present on the morning following operation,

at which time the left stellate ganglion was blocked. Within a few minutes the patient was able to name simple objects at command, and movement returned to the arm and leg. Daily injections were carried out for seven days, and at the end of this interval movements of the arm were excellent and she could walk without difficulty. Some aphasic difficulty remained, but full recovery of speech was obtained in six weeks.

In table 2 the results of stellate block in this group of patients without specific cerebrovascular disease are presented.

The response of one patient with a subdural hematoma was of considerable interest. After evacuation of a large, chronic, fluid hematoma on the left side the brain remained depressed a distance of 3 cm. from the dura. Within ten minutes after a stellate block it had expanded to its normal position, and after a second block on the next day the patient's hemiparesis completely and permanently disappeared.

Although there is a great variation in the degree and character of response following a stellate block, there are several features which

TABLE 2.—*Results of Stellate Block in Patients Without Cerebrovascular Disorders*

Diagnosis	Number	Result					
		Good	%	Fair	%	Poor	%
Neurologic defects, traumatic	59	22	37	28	47	9	16
Neurologic defects, postoperative							
Gliomas	5	3	60	1	20	1	20
Meningiomas	2	2	100	..	..	..	..
Angiomas	2	1	50	1	50	..	..
Metastatic tumor	1	1	100	..	..	..	..
Subdural hematoma	1	1	100	..	..	..	..
Total	70	30	43	30	43	10	14

remain constant. If a favorable response occurs in acute cases, it is manifest within five to ten minutes. The maximum benefit follows the first block, the effect diminishing with subsequent ones. Frequently a better response is obtained when the ganglion contralateral to the site of intracranial disease is blocked than when the injection is made into the ipsilateral ganglion. This is a common occurrence and is of interest in view of the experimental finding that the effect of stimulation of the cervical sympathetic chain is entirely ipsilateral.[3b] As yet the reason for this is purely in the realm of speculation, but we feel that the frequent effectiveness of a block of the stellate ganglion on the side opposite to the intracranial disease results from the development of a collateral circulation.

In order to understand better the clinical improvement following stellate block in these patients, we have studied the effect on the cerebral blood flow, using the technic of Kety and Schmidt.[7] Measurements were

7. Kety, S. S., and Schmidt, C. F.: Nitrous Oxide Method for the Quantitative Determination of Cerebral Blood Flow in Man: Theory, Procedure and Normal Values, J. Clin. Investigation **27**:476-483 (July) 1948.

carried out in 15 patients. In 1 instance the blood flow increased from 45 cc. per hundred grams per minute to 88 cc. per hundred grams per minute and the cerebrovascular resistance decreased from 1.5 to 0.62. No change was demonstrable in the remaining 14 patients from either ipsilateral, contralateral or bilateral blocks. Harmel and his associates have reported similar negative results in normal and hypertensive persons without neurologic deficits.[8] However, there may be a transient increase in the cerebral blood flow following a stellate block, as suggested by observing its effect on the spinal fluid pressure. In 7 patients the

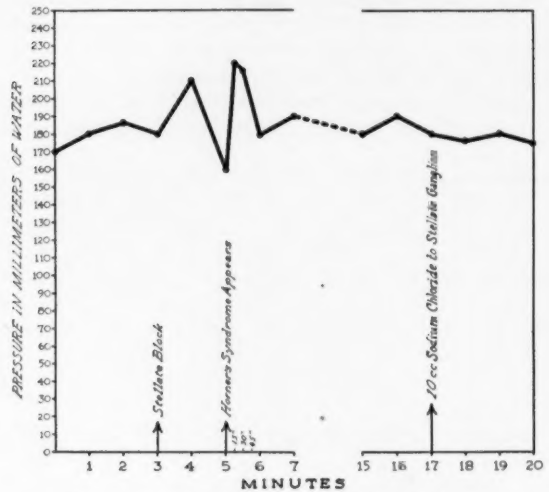

Fig. 2.—Effect of stellate block on spinal fluid pressure.

spinal fluid pressure was measured, a needle placed in position to block the stellate ganglion and, after sufficient time was allowed for establishment of a constant level of pressure, procaine hydrochloride was injected about the ganglion. In all 7 patients the pressure rose coincidentally with the appearance of Horner's syndrome. The rise varied from 25 to 50 mm. of water, and the pressure fell to the basal level in 20 to 40 seconds. No effect on the pressure was obtained by injection of isotonic sodium chloride solution (fig. 2). We have interpreted this response

8. Harmel, M. H.; Hafkenschiel, J. H.; Austin, G. M.; Crumpton, C. W., and Kety, S. S.: The Effect of Bilateral Stellate Ganglion Block on the Cerebral Circulation in Normotensive and Hypertensive Patients, J. Clin. Investigation **28**:415-418 (May) 1949.

as suggesting a transient increase in the amount of blood entering the cranium. The failure of a stellate block to exert a consistent influence on the cerebral blood flow and cerebrovascular resistance as measured by the technic of Kety and Schmidt may possibly be explained either by a change that is too slight to be discernible by this technic or by a redistribution of the blood flow through smaller vessels without a change in total blood flow. Further studies are in progress to elucidate this point.

Because of the excellent clinical results obtained in many of the patients with an acute lesion, the procedure has been extended to patients with neurologic defects remaining as a result of prior cerebrovascular accidents. We have been surprised to find improvement occurring as late as six years after the original vascular insult. In 15 cases this improvement has been sufficient (both clinically and electroencephalographically) to warrant surgical decentralization of one stellate ganglion or both. The cerebral blood flow was measured before and after the operation in 1 case and was found to be significantly increased. These cases will be reported elsewhere.

SUMMARY AND CONCLUSIONS

1. Functional interruption of the cervical sympathetic chain by a procaine injection of the stellate ganglion has been carried out more than 700 times in a total of 225 patients. One group of 155 patients had acute disorders of the cerebral circulation, namely, thrombosis, embolism or vasospasm. The remaining 70 patients were suffering from acute neurologic deficits associated with trauma or intracranial operations.

2. The results of this form of therapy are sufficiently gratifying to establish a definite place for it in the treatment of cerebral vascular disorders.

3. The physiologic basis for the clinical improvement is not understood, since alteration in the total cerebral blood flow as measured by the technic of Kety and Schmidt has not as yet been demonstrated.

4. That there may be a transient rise in total cerebral blood flow following a stellate block is suggested by a consistent rise in cerebrospinal fluid pressure for a period of twenty to forty seconds.

5. Improvement in the electroencephalographic tracing frequently accompanies the clinical improvement that is seen after block of the stellate ganglion.

INTRACRANIAL ANEURYSMS

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THE PROBLEM of intracranial aneurysms is an old one which has been revived in recent years as a result of improvements in diagnostic methods and technical aspects of surgical treatment. The chief reason for the renewal of interest in this subject is the recent development of cerebral arteriography. This procedure affords an excellent means of visualization of the normal and abnormal intracranial vessels, using as a medium a 35 per cent solution of iodopyracet injection (diodrast®). It is relatively simple to perform and safe from the standpoint of the patient, and it allows excellent roentgenographic visualization of the vessels. The procedure consists of the introduction of iodopyracet injection directly into the carotid artery, either by the percutaneous method or by the open procedure, with introduction of the needle into the carotid artery under direct vision. The choice of method depends on the experience of the operator and the frequency with which the procedure is done. The essential feature of the procedure from a technical aspect is the necessity of excellent cooperation with the department of roentgenology. Thus a technic can be developed for rapid exchange of cassettes during and immediately after the injection so that accurate visualization of the vessels can be obtained in both arterial and venous phases of cerebral circulation. The use of one of the many automatic rapid film changers simplifies the procedure from the radiographic standpoint, but satisfactory arteriograms can be obtained by manual exchange of the cassettes. The ideal arteriogram consists of the anteroposterior and stereoscopic lateral views during the arterial and venous phases. This requires roentgenograms taken after each of three injections, usually consisting of from 10 to 12 cc. of 35 per cent iodopyracet injection. It is customary to test the patient, before the procedure is carried out, with a small amount of the injection either subcutaneously or intravenously to note any individual idiosyncrasy to the drug.

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Read at the Fifty-Seventh Annual Meeting of the Western Surgical Association, Santa Barbara, Calif., Dec. 2, 1949.

Cerebral arteriography is the only adequate diagnostic method for visualization of the majority of primary intracranial vascular lesions, but it is also employed in the differential diagnosis and localization of intracranial tumors. The diagnosis is made on the basis of the vascular pattern in the tumor area as well as of the pattern of displacement of the cerebral vessels.

The increased usage of arteriography has led to the identification of a large number of primary intracranial vascular lesions before rupture and subarachnoid or intracerebral hemorrhage has occurred. The most specific indication for cerebral arteriography is in the localization of the lesion producing a spontaneous subarachnoid hemorrhage.

LOCATION OF ANEURYSMS

Since intracranial aneurysms are considered to be of congenital origin, it would be theoretically possible for an aneurysm to occur at any point along the myriad of intracranial vessels. However, clinical experience has shown that these lesions have a predilection for the anterior half of the circle of Willis, namely, that portion involving the carotid circulation. McDonald and Korb,[1] in a large series of aneurysms carefully investigated, have found that 75 per cent of the lesions involved the carotid half of the circle of Willis. In their series the internal carotid and middle cerebral arteries were involved in 48 per cent of the patients and anterior cerebral and anterior communicating arteries in 15 per cent. From the surgical standpoint, the statistics are of less importance than the fact that over three fourths of the aneurysms occur on the anterior half of the circle of Willis, which is surgically the most accessible. It is generally accepted that formation of aneurysm is secondary to weakness of the media of the artery or to abnormal development of congenital arterial buds. In spite of the vast amount of work which has been done on this subject, there remain many unexplained features which may be better understood as our experience with cerebral arteriography increases.

DIAGNOSIS OF ANEURYSMS

The high mortality which accompanies the initial rupture of an intracranial aneurysm justifies the use of cerebral angiography in any patient in whom such a vascular lesion is suspected. The extreme variability in location of the lesions and their frequent presence in a relatively silent area make for difficulty in establishing a clearcut clinical syndrome. Nevertheless, some of the signs and symptoms which may aid one in suspecting the presence of an intracranial aneurysm prior to rupture and serve as an indication for cerebral angiography should be discussed in more detail.

1. McDonald, C. A., and Korb, M.: Intracranial Aneurysms, Arch. Neurol. & Psychiat. **42**:298-328 (Aug.) 1939.

The presence of an intracranial bruit serves as the most definite indication of an intracranial aneurysm, and arteriography should be carried out in all patients in whom this is present. It is true that certain types of vascular tumors will produce a bruit, audible either to the patient or to the examiner, but a presumptive diagnosis of aneurysm should be made until the lesion is proved otherwise. Occasionally a bruit is audible to the patient but not to the examiner. It is possible from the nature of the bruit itself to determine whether one is dealing with an arterial or an arteriovenous type of an aneurysm. In the latter, the bruit is generally of a to-and-fro type and more or less constant throughout the cardiac cycle. In arterial aneurysms, a bruit is less likely to occur, but, if present, it is generally heard only during systole.

The development of a unilateral proptosis, particularly associated with engorgement of the conjunctival and retinal veins, is most commonly due to an arteriovenous aneurysm involving the carotid artery and the cavernous sinus, by means of which arterial blood is forced through the ophthalmic veins, producing a hydrostatic type of proptosis. All patients with such signs should be subjected to careful roentgenographic and ophthalmologic examination to exclude the presence of a space-occupying lesion, either intraorbital or intracranial with an intraorbital extension. Proptosis, secondary to an arteriovenous aneurysm, generally produces far less diminution of visual acuity than occurs with a retro-orbital tumor.

Occasionally adequate roentgenographic examination will disclose evidence of erosion of the inferior portion of the clinoid process on one side or unilateral erosion of the sella turcica. Lesions have been reported in which there was definite erosion of the posterior portion of the orbit, but it is seldom that such a lesion occurs without other localizing evidence due to the presence of numerous cranial nerves in that particular area. Frequently associated with bony erosion, linear streaks of calcification may be visible owing to the presence of calcium in the wall of an aneurysm.

One of the most frequent ocular lesions associated with an intracranial aneurysm is paralysis of the third nerve, which may occur alone or in conjunction with other localizing evidence. The proximity of the carotid artery to the optic nerve allows visual impairment to occur, frequently in the absence of any other positive findings. Abnormalities in the location of the optic chiasm make it possible for an aneurysm to produce direct pressure either on the optic nerve or on the optic chiasm. Lesions involving the optic chiasm produce homonymous types of visual defects, whereas the essential feature of a prechiasmal lesion is early loss of central vision due to involvement of the macular fibers.

Although headache is not a primary symptom of intracranial aneurysm, the presence of recurrent focal migraine-like headache over

a period of many years is sufficient to allow one to consider the possibility of an aneurysm as the underlying lesion. Frequently the headache is much more severe in character and less affected by the usual drugs which are employed in the treatment of migraine headache. A long history of such headache permits exclusion of the presence of a space-occupying intracranial tumor on the basis of time alone.

In addition to these more common symptoms, one may encounter as further evidence of an aneurysm such findings as a transient hemiplegia, visual hallucinations and convulsions as well as neuralgic pains in the first division of the fifth nerve or areas of numbness in the face. The symptoms are usually bizarre in character, and, particularly with arteriovenous aneurysms, the signs and symptoms may be atypical and frequently recurring over a period of years.

Rupture of an aneurysm seldom leaves any doubt in the mind of the patient or the examiner that a serious intracranial castrophe has occurred. The initial symptom is usually sudden, severe headache, frequently in the occiput, associated with marked meningismus and the presence of blood in the subarachnoid space. Depending on the location of the aneurysm, there may be no associated neurologic symptoms. This is true particularly with the initial episode of subarachnoid hemorrhage. The diagnosis can be confirmed by the presence of gross blood in the spinal fluid. These findings serve as a sound basis for a presumptive diagnosis of rupture of an intracranial aneurysm.

There exists considerable difference of opinion as to the proper time for arteriographic study to be undertaken subsequent to the initial subarachnoid hemorrhage. Some believe that the procedure should be done immediately as an emergency. Others desire to wait for a period of several weeks after the initial hemorrhage before any special diagnostic procedures are employed. The matter has not been decided, but the studies of Hamby [2] as well as those of Magee [3] clearly indicate the frequency with which second hemorrhage occurs. Obviously the proper time for arteriography, if it is to be employed, is prior to the onset of the second intracranial catastrophe. In Magee's series of 150 persons with spontaneous subarachnoid hemorrhage, 52 died during the first attack. Of the 98 survivors of the initial attack, 50 experienced a subsequent attack, 32 of whom died. Hamby's investigation revealed an equally discouraging rate of recurrences with a high mortality in each attack. It has been our policy to carry out arteriography as soon after the initial attack as the condition of the patient permits, this usually being somewhere between the tenth and twenty-first days in the hospital.

2. Hamby, W. B.: Spontaneous Subarachnoid Hemorrhage of Aneurysmal Origin: Factors Influencing Prognosis, J. A. M. A. **136**:522-528 (Feb. 21) 1948.

3. Magee, C. G.: Spontaneous Subarachnoid Hæmorrhage: Review of 150 Cases, Lancet **2**:497-500 (Oct. 23) 1943.

Bilateral arteriography may be necessary in persons presenting no positive neurologic signs, the procedure being carried out on the right side first, since this represents the hemisphere with the least localizing functions.

OPERATIVE TREATMENT

The operative attack on cerebral aneurysms is relatively simple in theory, the objective being the prevention of further bleeding from the site of rupture either by eliminating the lesion entirely or by so reducing the blood flow to the point of rupture that further bleeding will not occur. The direct methods consist of actual removal of the aneurysm itself or a trapping procedure consisting of placing a clip on the artery immediately proximal and distal to the aneurysm. The indirect method is ligation of the efferent blood supply at some point proximal to the lesion. Since the advent of routine arteriography, accurate localization of the lesion has become so successful that the surgical trend has been more and more toward direct operation and the actual attack on the aneurysm itself.

Ligation procedures are usually carried out at some point in the carotid system in the neck on one side. The most conservative of such procedures is ligation of the common carotid artery, which results in a partial reduction of pressure within the carotid system but does not completely eliminate the blood flow because of the anastomosis between the two external carotid arteries. It is likely that a further reduction in blood flow through the internal carotid can be accomplished by a combination ligation of the common carotid and the external carotid artery above the point of exit of the superior thyroid and lingual arteries, which thereby partially reduces the collateral circulation through the external carotid artery. The most satisfactory unilateral ligation procedure is that involving the internal carotid artery itself, which completely eliminates the blood flow through that half of the carotid system and probably materially reduces the pressure on aneurysms involving the ipsilateral portion of the circle of Willis. Ligation procedures in the neck, although simple from a surgical standpoint, are not without a certain degree of hazard. The procedure can be carried out more or less routinely in persons under the age of 35 years, but, even so, preoperative tests for collateral circulation by compression of the neck before operation should be carried out as a precautionary measure. If the patient is able to tolerate compression of the artery for a period of ten minutes to a half hour on several occasions without production of contralateral symptoms, it is probably safe to proceed with ligation of the internal carotid artery itself. Even the satisfactory results from preoperative compression do not eliminate the possibility of a postoperative complication. Frequently, within a period of twenty-four to thirty-six hours after ligation, cerebral symptoms may occur which apparently are due to progressive thrombosis

within the carotid artery itself subsequent to ligation. Such ligation may be carried out as an isolated procedure or may be the first step in a contemplated intracranial attack. Ligation of the internal carotid artery in the neck should never be done if the aneurysm involves the anterior cerebral or anterior communicating artery because this would eliminate all blood flow to the middle cerebral artery if it is necessary to clip the proximal part of the anterior cerebral or the communicating vessels.

The procedures usually employed in the direct approach consist of trapping the lesion between two silver clips, clipping the stalk of the aneurysm or direct excision. The methods of trapping the aneurysm consist of primary ligation of the internal carotid in the neck and then the placing of a clip on the main trunk of the arterial supply distal to the lesion. This is the most satisfactory method of coping with aneurysms arising from the intracranial portion of the internal carotid artery itself. However, lesions located immediately proximal to the bifurcation of the internal carotid into the middle and anterior cerebral arteries may be attacked by direct intracranial clipping on either side of the site of the aneurysm. A similar procedure can be carried out at almost any point along the anterior cerebral artery or on the anterior communicating artery itself provided this vessel is of sufficient length. Occasionally an arterial aneurysm of the circle of Willis may be found with a sufficiently long stalk to allow placing a clip directly on the stalk of the aneurysm adjacent to the main vessel. This procedure is the most satisfactory if it can be accomplished, because while it completely eliminates the source of bleeding it does not compromise any of the major arterial pathways. Occasionally a massive aneurysm may be encountered arising from a small vessel, in which case it is preferable to remove the lesion between silver clips because, on account of its size, it acts not only as a source of recurrent hemorrhage but also as a space-occupying intracranial lesion.

The technical aspects of the approach to the circle of Willis have been fairly well standardized with the exception of the position of the patient. During the past six years we have employed a position which we term the face-forward position (fig. 1) and which was originally designed as an improved method of direct attack on cerebral aneurysms.[4] The patient is placed on his abdomen with his neck extended, the head being held in a position which allows the floor of the anterior fossa to be slightly dependent but nearly horizontal. This allows a direct eye level approach to the lesion, which necessitates less retraction of the frontal lobe and affords a greater visualization at the site of the lesion than can be accomplished in a conventional position (fig. 2*a*). Furthermore, this method affords escape of spinal fluid and blood by gravity,

4. Shelden, C. H.; Pudenz, R. H., and Restarski, J. S.: A New Position for Frontal Craniotomy, J. Neurosurg. **2**:546-550 (Nov.) 1945.

thereby preventing the necessity of extensive use of suction. The head being higher than the heart level greatly decreases the venous pressure, thereby preventing cerebral congestion and allowing easier access to the site of the aneurysm. In the usual operative position for transfrontal craniotomy, the aneurysm and the circle of Willis occupy a position at the most dependent portion of the operative field, and in case the aneurysmal sac is inadvertently torn or a vessel escapes, the entire field

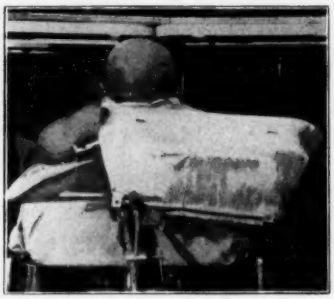

Fig. 1.—Position of patient using frontal head rest, allowing exposure of the entire vertex if necessary.

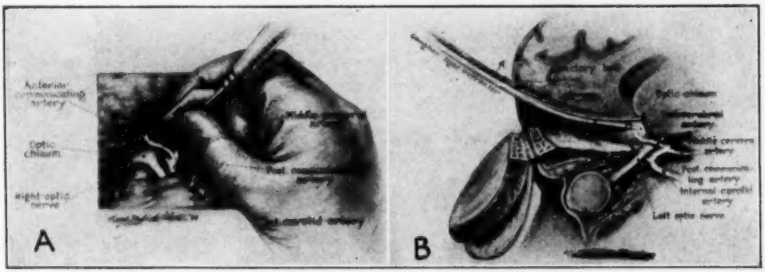

Fig. 2.—*A*, drawing from actual exposure of circle of Willis, showing excellent visualization of the chiasm and adjacent arteries. *B*, Drawing indicating method of approach to the chiasm and circle of Willis.

rapidly fills with arterial blood, which may be impossible to remove by suction rapidly enough to allow one to visualize the source of the hemorrhage. In the face-forward position this difficulty is overcome because the aneurysm itself and the circle of Willis occupy a position higher than the floor of the anterior fossa, and even with the most copious hemorrhage it is not difficult to find and clip the source of the bleeding (fig. 2*b*).

In the performance of transfrontal craniotomy, the bone flap should be large enough to allow approach to the lesion either along the floor of the anterior fossa or from above, between the frontal lobes. It is essential that the supraorbital limb of the craniotomy be as near the level of the floor of the anterior fossa as possible. An extradural approach is made as far as the sphenoid ridge, and then the dura is incised and for the remaining distance to the aneurysm an intradural procedure is used. It may be found that the aneurysm is situated high on the anterior

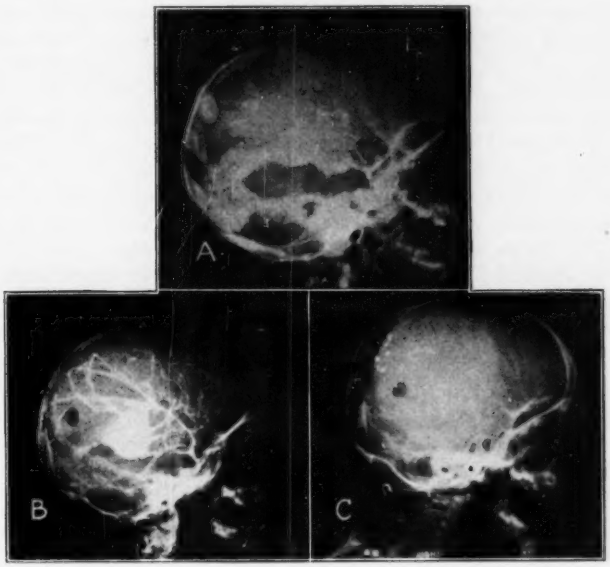

Fig. 3.—*A*, arteriogram showing large midline arteriovenous aneurysm. *B*, midline arteriovenous lesion showing efferent arterial supply. *C*, roentgenogram taken postoperatively, after ligation of the arterial supply to the arteriovenous aneurysm shown in *B*. There are metallic clips on the smaller vessels. Several larger arteries were ligated with heavy silk ligatures which are not visible in the roentgenogram.

cerebral artery, in which case it may be more advantageous to approach the lesion from between the frontal lobes. Even in such instances it is essential that the original approach be made along the floor of the anterior fossa, as this allows one far better control of the efferent blood supply in case an extremely copious hemorrhage should occur.

The surgical management of arteriovenous lesions of the brain presents formidable technical problems. The simplest of such problems

involves the carotid artery and the cavernous sinus, which can generally be adequately controlled by ligation of the artery proximal and distal to the site of the fistula. Arteriovenous aneurysms involving the convexity or the cerebrum itself are frequently too widespread for adequate surgical attack even after satisfactory localization of the lesion by arteriography. Block resection with removal of the entire arteriovenous fistula can occasionally be successfully accomplished, and no doubt in the future this method will be amplified. As experience increases, it may be that the majority of these lesions can be adequately removed. The large midline aneurysms involving the vein of Galen and the straight sinus can be treated successfully if a two stage procedure is employed (fig. 3 *a, b*). At the first stage of the operation, an occipital craniotomy is carried out, with division of the tentorium and the falx cerebri. The aneurysm is gradually dissected free and the major vessels visualized. A thin layer of gelatin sponge is packed around the gourdlike lesion, particularly about the large efferent vessels, and the wound closed. After a period of ten days the wound is reexplored. During this interval, swelling of the gelfoam® has produced a hydrostatic dissection of the brain from the aneurysm. When the gelfoam® is removed by suction, there exists ample room for easy ligation of the large vessels entering the aneurysm (fig. 3 *c*).

SUMMARY

The problem of intracranial vascular lesions has come to occupy a prominent place in modern neurosurgery. Arteriography has materially aided in proper diagnosis and has afforded a sound basis for direct surgical treatment. Technical advances are constantly increasing the scope of this aspect of neurosurgery, and it is anticipated that in the near future many lesions now considered inoperable will be amenable to successful management.

DISCUSSION

DR. GLENN H. BELL, San Francisco: Dr. Sanders, I do not think that a general surgeon should try to discuss a neurologic subject, but Dr. Adams has brought to our attention a condition that we encounter not only in neurologic patients but also in general surgical patients. One only has to see the spectacular change after a stellate block in one or two of these cases to realize that perhaps we, as general surgeons, should learn—if the neurosurgeons will let us—how to do stellate blocks. To see the reaction in a patient after a stellate block when he gets the use of an arm or leg back is nothing more than spectacular.

DR. FRANK M. GREM, Chicago: I should like to reemphasize Dr. Adams' suggestion that this form of therapy be utilized more and more for cerebral vascular accidents. I have been fortunate in having been able to perform or supervise the blocking of the stellate ganglion in 350 patients in the last two and a half years. I should like to pass on one or two points which I have learned from blocking the ganglion in patients with cerebral vascular accidents.

The anterolateral approach is the one of choice. The posterior approach is cumbersome and, because of the condition of the patients, is apt to be most difficult. In the anterolateral approach the block can be easily effected by having the patient in the supine position with the head turned to the side opposite to that on which the block is to be made and with the upper extremity on the side to be blocked at the side of the body. The tubercle of Chassaignac can be easily palpated and a skin wheal raised 2 cm. below this point. A 2 inch (5.08 cm.) needle is inserted perpendicularly to the skin until it makes contact with the transverse process of the seventh cervical vertebra. If the direction of the needle is changed to a 45 degree angle with the sagittal suture of the body and moved one half inch (1.27 cm.) along the anterior surface of the transverse process of the seventh cervical vertebra and injection made after aspiration at this point, the stellate ganglion block is effected. The posterior approach has been followed by a higher incidence of such complications as pneumothorax and hematoma. The blocking of the stellate ganglion in patients with cerebral thrombosis and cerebral embolism has produced gratifying results. In patients with cerebral hemorrhage, poor results have been obtained from blocking the stellate ganglion. The question has arisen of whether or not the block should be done in cases of hemorrhage. I feel that it should be done after the first or second day and not earlier. A block done after this time will be helpful because it will relieve the spasm of collateral vessels which is present and which in itself would produce more irreversible changes than the original hemorrhage itself. The criterion to be used is that the patient's response to the block should be immediate, that is, in the matter of a few minutes. Without treatment, it is true, improvement may occur in a matter of hours but never in a matter of minutes. If a block is performed and a favorable response is obtained, such as regaining of consciousness, regaining of speech or return of motor functions, all in a matter of minutes, this can be correctly attributed to the block and not to spontaneous recovery.

Dr. John E. Adams, San Francisco: I certainly think that anybody can use this technic. It is relatively simple and safe. We, too, feel that the posterior approach should not be used. It is difficult and painful and is certainly attended by a much higher rate of morbidity and complications. We have used the lateral approach but have given that up because in a few patients paratresia has resulted. It has been much more satisfactory when the needle has passed closer to the brachial plexus in the anterior.

I think the results are, without question, best in the group who have cerebral embolism, because as a rule this is a younger group of patients. Many of them have come from the obstetric wards and many from general surgical wards. They have, on the whole, responded better.

I should like to emphasize again the fact that we are now directing our attention more to the patients who have suffered a cerebral vascular accident in the past, and in these the effect of a block on the residual hemiplegia or aphasia has been extremely surprising to us. After a period of years, even, these patients may be benefited. Perhaps there are cells which are lying dormant, so to speak, sufficiently nourished by blood to be viable but not to function properly.

In the past three months we have used a catheter in a number of patients instead of doing multiple blocks, which sometimes tend to wear the patient out. We have used a technic of merely introducing a spindle needle into the region of the stellate ganglion and passing a small catheter. This is left in, and every four to five hours procaine is instilled into the catheter and continuous block is maintained by that means.

I should like to ask Dr. Shelden one point about his paper. We, too, have had difficulty in approaching aneurysms by the circle of Willis, and in the last few years we have utilized a more lateral approach, going along the sphenoidal ring and elevating the temporal lobe in addition to the frontal lobe. I wonder whether he has used that method of approach in attacking these lesions.

DR. C. HUNTER SHELDEN, Pasadena, Calif.: In answer to Dr. Adams' question concerning the method of approach, we also have used the other method of approach in conjunction with this one along the floor of the anterior fossa. We feel that it is best to approach the lesion initially along the floor of the anterior fossa, which is essentially not much different from the approach along the sphenoidal ring. After that approach has been made, if the location of the lesion is such that a more lateral or more superior approach will allow a better attack on the aneurysm itself, that can be used.

The reason for approaching the lesion along the floor of the fossa first is the efferent source of blood supply, and when attacking such a lesion it is well to have the opportunity of pausing in case there is a large hole in the lesion.

EXCISION OF THE SKIN IN RADICAL MASTECTOMY

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TUCSON, ARIZ.

IT IS GENERALLY agreed that the operation of choice for carcinoma of the breast is radical mastectomy based on most of the concepts of Halsted and of Willy Meyer. No general agreement exists, however, on the amount of skin that should be removed in the performance of the operation. There are those who advocate removing a large amount of skin and covering the raw areas with skin grafts and those who allow enough skin to remain for a primary closure. The first group, or the "Halsted group," apparently believe that the cancer is spread by permeation and embolism into the lymphatic vessels to the skin. The second group subscribes to the conclusion of Handley,[1] who believed that the spread of cancer was through the vertical lymphatic vessels. Both groups agree that embolism, permeation and, more rarely, vascular routes are available for dissemination of the carcinoma. Since the exact route of metastasis in the skin has never been definitely established, the argument still remains. The instance of axillary metastasis is extremely high in patients with recurrences in the skin, and it seems probable that retrograde lymphatic flow with embolism is a factor in this recurrence.[2] A number of recurrences in the skin are possibly due to transplants, as many of them involve the line of incision. Brown [3] reported 3 cases of late recurrences that he believes were caused by transplantation of the tumor by stitch holes at the time of operation.

Lewis and Reinhoff [4] studied the Johns Hopkins Hospital cases from 1889 to 1931 and concluded that it was incumbent on the surgeon

Read at the Fifty-Seventh Annual Meeting of the Western Surgical Association, Santa Barbara, Calif., Nov. 30, 1949.

1. Handley, W. S.: Cancer of the Breast and Its Treatment, ed. 2, New York, Paul B. Hoeber, 1922.

2. Oliver, D. R., and Sugarbaker, E. D.: The Significance of Skin Recurrences Following Radical Mastectomy, Surg., Gynec. & Obst. **85**:360, 1947.

3. Brown, A.: Later Recurrences in the Skin Following Radical Amputation of the Breast for Carcinoma, Quart Bull. Northwestern Univ. M. School **20**:18, 1946.

4. Lewis, D., and Reinhoff, W. F., Jr.: A Study of the Results of Operations for the Cure of Cancer of the Breast, Performed at Johns Hopkins Hospital from 1889 to 1931, Ann. Surg. **95**:336, 1932.

to perform a far wider resection of skin than had been customary with the original Halsted technic. They stated that in this condition alone exists the possibility of reducing local recurrences to a minimum. In a comparison of the average length of life in patients in whom wide excision of the skin and a graft were carried out and in those in whom primary closure was done, the figure was 3.82 years for the former and 3.15 years for the latter.

Conway and Neumann [5] studied a series of 255 patients subjected to radical mastectomy for carcinoma of the breast and compared the local recurrence rate in the wounds which had been grafted and in those for which primary closure had been used. For the grafted wounds the rate of local recurrence was 21 per cent, while for the ungrafted wounds it was only 6 per cent. To be certain that this difference was not due to the possibility that the grafting had been used more frequently in large tumors (which have been shown to cause more frequent recurrence), the tumors were divided into two groups, the small ones and the large ones. In 154 cases of small tumors (0 to 5 cm.) in which a graft was used there was a 16 per cent local recurrence, and in the 62 cases of ungrafted wounds there was a 6 per cent recurrence. Of 107 patients with axillary metastasis in whom grafts were used, recurrence developed in 25 per cent, and in 32 patients with axillary involvement whose wounds were closed without skin grafts, a recurrence rate of only 6 per cent was found. Yet, paradoxically, in conclusion, the authors suggested that more radical excision of skin be done at the time of operation.

In an investigation of 254 cases of malignant tumors of the breast with a five year follow-up study, White [6] found that the local recurrence rate after radical mastectomy and primary closure was 19.7 per cent. In cases in which closure was done by grafting there was a 28 per cent local recurrence. He emphasized that in all cases with local recurrence death was caused by distant metastasis and not by the cancer in the area of the operative field and concluded that in his experience no patients had been lost because a wider excision of skin had not been made.

Harrington [7] believed that cutaneous flaps can be approximated with "little or no danger of recurrence in the skin."

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5. Conway, H., and Neumann, C. G.: Evaluation of Skin Grafting in the Technique of Radical Mastectomy in Relation to Local Recurrence of Carcinoma, Surg., Gynec. & Obst. **88**:45, 1949.

6. White, W. C.: Skin Removal in Radical Mastectomy, Ann. Surg. **115**:1182, 1942.

7. Harrington, S. W.: Results of Radical Mastectomy in 5026 Cases of Carcinoma of the Breast, Pennsylvania M. J. **43**:413, 1940.

Fig. 1.—Diagram on the left shows incision with points *A* and *B* marked for Z-plasty closure. Diagram on the right shows method of closing flaps.

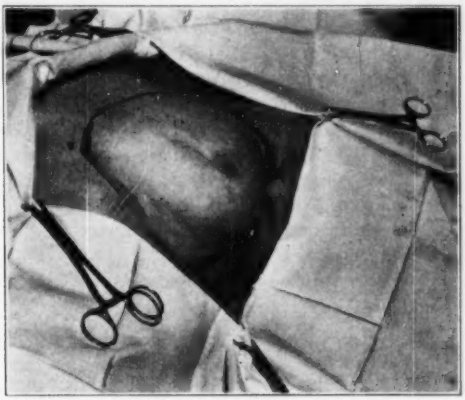

Fig. 2.—Large tumor of lower half of the breast. Amount of skin to be excised marked off, showing line of incision.

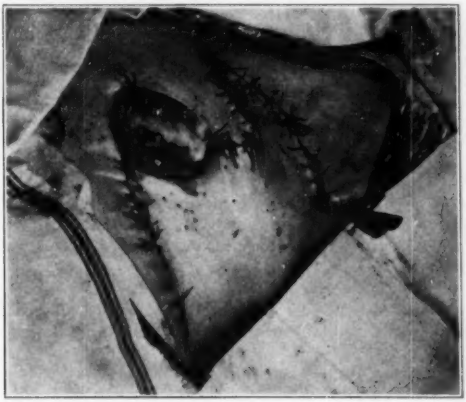

Fig. 3.—Closure by Z-plasty illustrating the relatively small amount of skin graft needed to cover remaining raw area.

Rodman [8] wrote that skin grafting is unnecessary except in the rarest of cases, stating that he had not done it since 1908. In 132 of his private cases the local recurrence rate was 2.2 per cent. His low recurrence rate may be due to the class of patients who were followed. A detailed study of cancer of the breast by Haagensen and Stout [9] revealed that five year local recurrences were twice as high in their ward patients (28.2 per cent) as in their private patients (12.4 per cent). A comparison of 225 tumors grafted by the Halsted method and 238 in which primary skin closure was used was made by White. The incidence of recurrence for the grafted tumors was 35 per cent as compared with 22.6 per cent for the others. In a series of 450 cases of carcinoma of the breast, Oliver and Sugarbaker [2] found local recurrence in 26. Fourteen of the wounds were grafted, and 12 had flap closures. Sufficient time had not elapsed in some cases, however, for the inevitable recurrence in the skin which would bring the recurrence rate up in a five year period. Wide excision of the skin would not, in these authors' opinion, improve the five year survival rate of patients.

Rector [10] has just surveyed a series of 96 cases of cancer of the breast which extends from 1934 to 1948, and, he concluded his study by stating: "Wide skin excision and grafting is not the answer to the prevention of skin recurrences."

Finney and others [11] studied 298 consecutive cases of cancer of the breast and found a 10 per cent local recurrence rate for the grafted wounds and less than a 6 per cent recurrence for the primarily closed wounds.

Marshall and Hare [12] intentionally limited the extent of skin excised in order to obtain early primary healing for the purpose of early irradiation. By this procedure they raised their five year survival rate from 38.6 to 52 per cent and local recurrences developed in only 8 per cent.

Eberbach,[13] in a series in which primary closure was usually done, noted only a 1 per cent recurrence rate in patients without axillary metastasis.

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8. Rodman, J. S.: Skin Removal in Radical Breast Amputation, Ann. Surg. **118**:694, 1943.

9. Haagensen, C. D., and Stout, A. P.: Carcinoma of the Breast, Ann. Surg. **116**:801, 1942.

10. Rector, E. W.: The Relation of the Incidence of Local Skin Recurrence Following Radical Mastectomy to the Area of Skin Excised, to be published.

11. Finney, G. G.; Merkel, W. C., and Miller, D. B.: Carcinoma of the Breast, Ann. Surg. **125**:673, 1947.

12. Marshall, S. F., and Hare, H. F.: Carcinoma of the Breast: Results of Combined Treatment with Surgery and Roentgen Rays, Ann. Surg. **125**:688, 1947.

13. Eberbach, C. W.: Carcinoma of the Breast, Wisconsin M. J. **48**:132, 1949.

It was believed that it would be of interest to canvass the members of this organization to determine what their opinions were of the amount of skin which should be removed in the performance of radical mastectomy, since the subject is, as yet, controversial. Letters were sent to all active members of the Western Surgical Association, excluding those who were known to confine their surgical efforts to a field apart from surgery of the breast. Eighty-five letters with information were received. A summary of these letters is of no statistical value. One writer began his letter by stating that he was dubious of mass opinion or even majority opinion unless it be supported by good evidence. I believe that the experience of men belonging to this Association may balance the lack of statistics and offer worthy evidence as a result of clinical observation. It may be said, generally, that the large majority favored leaving enough skin to permit primary closure.

Seventy of the eighty-five members are doing primary closures in a great majority of their cases; four did not state whether skin grafts or primary closures were used and eleven were applying skin grafts to most of the wounds according to the original Halsted technic.

A further break-down was made, which included only those men from universities or medical centers where large numbers of operations were performed and where a more complete follow-up study could be done. Fifty-eight of the sixty-five in this group were using primary closure in the majority of their cases and seven were applying skin grafts for closure.

It is, of course, impossible to do a primary closure in every case. A number of factors prevent it in some instances, such as a small breast, a large tumor, edema of the skin outside the boundaries of the tumor, ulceration, location or depth of the tumor, wide fixation of the skin to the malignant growth or unexpected tension on the suture line. The amount of skin to be removed is a problem of surgical judgment, varying to some degree in each instance. The distance suggested between the line of incision and the palpable edge of the tumor varied from 1 to 4 inches (2.54 to 16.16 cm.) for tumors which were deep and not attached to the skin and when no edema of the skin was present, the majority placing the incision from 2 to 3 inches (5.08 to 7.62 cm.) from the tumor edge. In cases of skin fixation, ulceration or carcinomatous edema of the skin, no definite suggestions were made except that most of the skin of the breast should be removed. An expression in one letter typified the general feeling of the members: "In those cases we take a large amount of skin but do so with our tongues in our cheeks because who can say just how wide the dissemination has been?"[14] Another

14. Mathewson, C.: Personal communication to the author.

said: "Work in these cases is hopeless anyway."[15] This was the type of case that was excepted in primary closure by the first group. The type of tumor or grade of malignancy made no difference in the amount of skin excised. Several members remove more skin when axillary metastasis is present.

The advantages of primary closure include more rapid healing, early institution of postoperative irradiation, a smoother postoperative course, a better cosmetic and functional result and shortening of the operating time.

Our president, Dr. Sanders, wrote: "This may be rank heresy, but I have seen so few local recurrences after primary closures that I am convinced that one should remove only a sufficient amount of skin to permit approximation after the breast has been removed." Other quotations are as follows: "I feel that the removal of a large amount of skin in radical mastectomy is in line with many traditions in surgery that should be abandoned. Roentgen ray therapy is improved and may explain the low recurrence rate" (A. Jackson). "The necessity of removing a large amount of skin has been greatly exaggerated."

The term "wide excision" is vaguely used in the literature as well as in the letters received. One must assume, however, that if the wounds from radical mastectomy are closed primarily without skin grafts, the amount of skin removed is not as extensive as that removed by Halsted. Regardless of the type of incision, if a large enough piece of skin is removed, it will be impossible to do a complete closure without the use of grafts.

If the incision is carefully planned according to the location of the tumor and the tumor is made the center of an elliptic incision, vertical or transverse, with the distance between the edge of the tumor and the incision no more than 2 inches (5.08 cm.), most wounds can be closed primarily without too great tension. There are exceptions, of course, such as those enumerated previously. I have found that the use of Z-plasty of the flaps allows closure with less tension and have used this procedure a number of times, with satisfactory results. I usually use the Rodman incision or a modification of it.

In the performance of the operation, it would seem as important to change instruments, gloves and drapes after resection of the axilla with metastasis as after the primary removal of tissue from the breast for biopsy. As a consequence, it is recommended that this be done, since it has been proved that cancer cells can be implanted in the wound.

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15. Gilchrest, R. K.: Personal communication to the author.

There is need for further pathologic and histologic study on the lymphatic vessels and the skin of the breast associated with carcinoma before one can be absolutely dogmatic in giving a complete answer to this problem. It seems a logical conclusion, however, after a review of the literature and of the results from the questionnaire, that one can usually plan a primary closure of the wound after a radical mastectomy without decreasing the survival years and, in fact, with the hope of increasing them by allowing postoperative irradiation to begin at an earlier date.

Halsted's dictum that the surgeon should perform the complete excision and have his assistant close the wound is possibly a passé surgical axiom.

TECHNIC FOR RADICAL MASTECTOMY

W. E. LEIGHTON, M.D.
ST. LOUIS

THE RADICAL operation for cancer of the breast dates from the epoch-making paper of W. S. Halsted [1] of Nov. 2, 1894. The principle enunciated at that time not only established the essential factors necessary for the eradication of cancer of the breast but paved the way for the more radical operations for cancer in other parts of the body, such as the lip, penis, tongue and uterus. Halsted's work followed the researches of a large number of investigators in surgery of the breast.

Up to the year 1860 cancer was generally accepted as a constitutional disease and it was thought that little could be gained from surgical intervention. That there were a few dissenters to this opinion is found in the writings of Sir Ashley Cooper and of Velpeau. Cooper,[2] in discussing the anatomy of the mamma, described scirrhous cancer as having roots running from the primary tumor and stated that operation to be effective must include removal of the roots. Velpeau [3] prior to 1860, reported on a number of patients with cancer of the breast living and well from three to five years and longer after operation and from his own experience showed unquestionably that cancer of the breast was curable.

To Sir Charles Moore [4] of London belongs the credit for first suggesting a radical operation, which he did in a paper published in 1867 disputing the constitutional theory of cancer. He advocated removing the axillary glands and fat, the fascia covering the pectoral muscles and any part of the pectoral muscle involved together with the breast. He also taught the advisability of the removal of the tissues en masse without cutting across the infiltrating areas. This remarkable paper was entirely ignored by English surgeons but stimulated Continental surgeons, especially the Germans, and the names of Waldeyer, Heidenhain, Volkmann, Kuster and others can be found contributing to the growing knowledge of the disease. Studies of the lymphatic drainage of the breast by Waldeyer and the investigation by Heidenhain proving the early involvement of fascia and muscles contributed to the gradual

Read at the Fifty-Seventh Annual Meeting of the Western Surgical Association, Santa Barbara, Calif. Dec. 2, 1949.

1. Halsted, W. S.: Johns Hopkins Hosp. Rep. **4**:1, 1894.

2. Cooper, A., cited by Leighton, W. E.: J. Missouri M. A. **36**:157 (April) 1939.

3. Velpeau, A. A., cited by Leighton.[2]

4. Moore, C., cited by Leighton.[2]

evolution of the complete and truly radical operation twenty-seven years later with which the names of Halsted, Willy Meyer, Volkmann and Sir W. Watson Cheyne will always be associated.

A comparison of the statistics prepared before Moore's paper and in the intermediate period or evolutionary stage of radical surgery of the breast with those in the era following the adoption of the radical operation of Halsted is both interesting and instructive. In 1878 Billroth [5] had only eight cures in 143 cases of cancer of the breast, or 5.6 per cent of cures. In the period before radical operations only from 4 to 5 per cent of patients were cured. In the evolutionary period, with a better understanding of the disease and more extensive operation, there was a higher percentage of cures, and with the advent of the radical operation the incidence of five year cures has risen to about 40 per cent. In the statistics presented at the Congress of Surgeons in Chicago in 1933, the incidence of five year cures in cases in which the breast alone was involved varied from 62 to 71 per cent, and when the axilla was involved it varied from 24 to 30 per cent, making a total of about 40 per cent five year cures in both groups. Up to January 1944 Harrington [6] of the Mayo Clinic traced 5,734 operative cases. Thirty and five-tenths per cent of patients who had axillary metastasis at operation lived 5 years, and 75.8 per cent without axillary metastasis at operation lived five years, a total of 48.1 per cent five year survivals. Harrington commented:

> Although axillary nodal metastasis is only one of the factors that may indicate the extent of the disease at the time of operation, I believe that it is one of the most important factors indicating the prognosis following operation because of the great influence that it has on the survival rates. Because of this fact, in compiling statistical studies of the survival rates of malignant diseases of the breast, I believe that all cases should be divided into two main groups, those with and those without axillary nodal metastasis at the time of operation, and that statistical studies should never be based on a combination of the groups, without knowing the number of patients in each group.

Since the early days of the radical operation, surgeons on the staff of the Massachusetts General Hospital have reported results in three to five year periods as follows:

Period	Percentage of Cures
1894-1904	19
1911-1914	27
1918-1920	30
1921-1923	35
1924-1926	41
1927-1929	43
1930-1932	45
1933-1935	51

5. Billroth, cited by DaCosta, J. C.: Modern Surgery: General and Operative, ed. 8, Philadelphia, W. B. Saunders Company, 1919, p. 1587.

6. Harrington, S. W.: Surgery **19**:154 (Jan.) 1946.

In 1947 Taylor and Wallace [7] reported the follow-up in 236 cases in the period 1933 to 1935. He pointed out that a factor of utmost importance in prognosis is the presence or absence of axillary metastasis. While the total incidence of cure was 50.4 per cent, the incidence in patients without axillary metastasis was 75.5 per cent, while in those with axillary metastasis it was only 33.3 per cent. The operative mortality in the present series was 2 per cent. While immediate exploration of the tumor is ordinarily considered to be innocuous provided proper precautions are taken, it was found that recurrence in the operative field took place in 15 per cent of cases in which biopsy was performed as compared with 7.5 per cent of those in which it was not. In his summary Taylor stated that roentgen therapy was employed in inoperable and recurrent cases but only rarely prophylactically after operation. It cannot be demonstrated to have any effect on the prognosis as employed in this group of cases.

These elaborate summaries would seem to justify and confirm a statement of Rodman [8] made in 1908 that surgical treatment should effect a cure in one half of all cases of cancer of the breast provided the patients can be subjected to the complete radical operation early in the disease. Since the time of Galen, when the breast was removed with a single stroke of the knife and the wound cauterized not only to stop bleeding but also to destroy fragments of cancer left behind, there have been many surgical procedures and numerous skin incisions, each an endeavor to eradicate the cancer or improve the operative result. From the transverse ellipse incision of LeDran, the oblique ellipse incision of Lizar, the incision of Pancoast with extension to the axilla and the dinner plate incision of Gross to the complete radical operation of Halsted and Willy Meyer, there has been steady, if slow, improvement in the resulting number of successful operations. That there was something to be desired in either the cosmetic or the functional result is shown in the varied modifications employed. Among them I might mention the operations of Kocher, Percy, Bulloch, Maclean and others who have offered valuable contributions for improvements in this field.

As a further contribution, while recognizing that no one incision is suitable for all cases of malignant tumors, I am presenting one which has been most satisfactory in meeting the requirements of a radical surgical operation for many cancers of the breast.

Any operation for the removal of a cancer of the breast must take into consideration three essential steps. First, the incision should be so

7. Taylor, G. W., and Wallace, R. H.: S. Clin. North America **27**:1151 (Oct.) 1947.

8. Rodman, W. L.: Diseases of the Breast with Special Reference to Cancer, Philadelphia, P. Blakiston's Son & Co., 1908, p. 254.

planned that it will circumscribe the skin over the breast at least 2 inches (5 cm.) from the margin of the tumor and that it can be extended to expose the contents of the axilla and the anterior rectus sheath at the epigastric triangle. Secondly, it must facilitate the removal of not only the anterior sheath of the rectus abdominis muscle but a wide area of the deep layer of the superficial fascia, with breast, both pectoral muscles, all axillary fat and lymph nodes as well as the fascia overlying the external oblique, the serratus anterior and the latissimus dorsi muscles. Thirdly, it must be planned, when the location of the tumor permits, for a closure of the operative wound with the least impairment of function of the arm and the best cosmetic result. Closure of the wound, however, should be a consideration secondary to the removal of the tumor.

Since April 1939 I have been employing an incision which evolved out of a repair of a Stewart incision for cancer of the breast. The incision begins over the latissimus dorsi muscle in the posterior axillary line at the junction of the arm and body. It extends downward and curves forward along the margin of the breast to form the lower edge of the oblique ellipse which circumscribes the breast with the tumor in the center. About 3 or 4 inches (7.6 to 10 cm.) below the beginning of the first incision a second incision curves upward and inward over the breast to form the upper edge of the ellipse, then curves downward to meet the first incision over the rectus muscle and continues on to the level of the costal border or midway to the umbilicus. The tumor should form the center of the ellipse, the edges of which should be at least 2 inches (5 cm.) from the tumor margin. This incision can be employed for at least 75 per cent of all tumors, i. e., practically all except those of the upper and inner quadrant.

The upper flap is undermined readily to the clavicle and sternal border by undercutting. Only a sufficient layer of superficial fascia should be preserved to nourish the skin. The sternal portions of the pectoral muscles are divided at their insertions. The axillary fascia, fat, lymph nodes and sheaths of the axillary vein, which is removed from the anterior margin of the latissimus dorsi to the costocoracoid ligament, are cleanly dissected from the axilla. All the branches of the axillary artery and vein which supply the breast and axilla are ligated and divided with the exception of the thoracodorsal vessels. The anastamosis of the thoracodorsal vein at the chest wall is preserved if possible. The long thoracic and thoracodorsal nerves are guarded carefully from injury. After the axillary space has been cleaned out, the rest of the upper and inner flap is undermined and the deep fascia and anterior sheath of the rectus abdominis muscle are removed from within outward. The lower flap then is undermined and the axillary contents, both pectoral muscles and the anterior sheath of the rectus together with the breast and deep

layer of the superficial fascia, are removed en masse. The resulting wound usually is brought together easily. If a triangular piece of skin is excised from the upper outer and lower inner flaps, there will be no redundancy of tissue and a smooth-appearing closure is obtained. The scar is "S" shaped.

In the period 1939 to 1941 I reviewed the cases of radical mastectomy in which this incision had been used at the Barnard Free Skin and Cancer Hospital. Of 105 patients traced, 71 had axillary metastasis, and of these 25, or 35 per cent, lived. Thirty-four had no axillary metastasis, and of these 30, or 88 per cent, lived. This makes a total of 52 per cent survival for five years or more. Dr. John Ellis, resident surgeon, reviewed the cases from 1942 to 1944. Of a total of 170 patients operated on, 88 lived, and, in spite of an incidence of axillary metastasis of 67 per cent, 52 per cent of the entire series survived five years or more. In the first 105 cases there were no swollen arms and only one recurrence at the scar of operation.

SUMMARY

A new technic of radical mastectomy is described. The results of this method compare favorably with those of other technics. The line of the ellipse is more in the natural tension lines of the skin. The upper end of the scar is in the posterior axillary line overlying the long axis of the latissimus dorsi muscle and does not infringe on the axilla, and it in no way comes in contact with the axillary vessels and does not hamper the motion of the shoulder. The cosmetic effect is ideal in that there is no visible scar on the upper thoracic wall.

DISCUSSION

DR. DEAN SAUER, St. Louis: I should like to express my appreciation to Dr. Cogswell and to Dr. Leighton for their fine presentations and to thank them for calling to our attention and reemphasizing certain points in the data and technic which cannot help but materially assist us in the eradication of a malignant growth whose total extirpation is so necessary to the preservation and prolongation of life.

I have been privileged to work with Dr. Leighton at the Barnard Hospital and to receive at his hand a great deal of my training, especially in cancer surgery, and it has been my observation that the use of his incision permits the ready application of the technics so fundamental in the removal of a malignant tumor of the breast. It gives wide exposure of the axilla from the cervicoaxillary canal and costocoracoid ligament to the lower border of the teres major muscle. One can expeditiously remove all the axillary contents, both the pectoral muscles and the breast, with the upper third of the rectus sheath. Further, the combined use of the Leighton incision with the preservation of the thoracodorsal branches of the subscapular vessels has helped materially in the reduction of postoperative disability and edema.

SIR HENEAGE OGILVIE, London, England: I am glad to speak on this occasion, because I did feel that this matter of cancer of the breast is one on which our two countries differ fairly radically. You all know that the Edinburgh school at present

is selling the idea that the right treatment of cancer of the breast is simply excision of the tumor, followed by high voltage roentgen ray therapy for the axillas. Now I do not want you to think from the literature that anybody outside Edinburgh has bought that theory. We feel that there are possibly further disastrous mistakes. All our experience, whether based on postmortem or on postirradiation excision, is that irradiation does not actually kill cancer cells. Always—and that is the experience of Mininger in London—some cancer cells are found afterward.

On the other hand, we feel that there is a tremendous gap between the patient to be treated surgically and the patient to be treated roentgenologically. Surgical intervention in the first stage, the proper stage, gives a 100 per cent incidence of cure because in stage one there is a tumor only. Clinically, most surgeons get about 85 per cent of five year cures in stage one. When surgical treatment fails to produce complete eradication of the disease, its results are often disastrous, and I think that there is nothing more dreadful than the failure of a surgical excision for cancer of the breast. The whole chest wall is involved in the recurrence.

While radiotherapy never cures a patient, its ability to kill most of the cells and to lock up the rest in scar tissue is dramatic, and, of course, we are all familiar with patients with an obviously inoperable cancer of the breast who have lived in reasonable comfort at least ten years before they finally died.

We often discuss the virtues of a surgeon, his courage or judgment. The vice of a surgeon, I think, is his Elizabeth Arden outlook, one of the worst things in surgery for cancer of the breast. About 25 per cent of recurrences are in the skin, 25 per cent in bones, 25 per cent in the area above the clavicle and the remaining 25 per cent over the rest of the body. Recurrence in the first is the one that should never happen. The recurrence in the scar is due to insufficient removal of skin, and the insufficient removal of skin is due to that desire for a cosmetic effect. In most cases the good scar is the signature of the good surgeon, but in surgery for cancer the only criterion is the widest possible removal of disease and the most thorough attempt to save life. I do feel that some of the tumors shown on the screen today were beyond surgical extirpation. The patient with the enormous tumor of the chest wall was bound to die of recurrence. It seemed to me that the figures shown were high. The high proportion of recurrences in cases after skin grafting suggests that those cases were unsuitable for operation and that the surgeon, in a courageous attempt to get beyond the disease, removed a great deal of skin but failed to cure the patient.

There is one other point in regard to the incision of Dr. Cogswell. Does the transverse incision in the axilla, while functionally satisfactory, make it difficult to get that radical clearance of axillary contents which is really successful?

Dr. Howard D. Cogswell, Tucson, Ariz.: If we accept Haagensen and Stout's criteria of inoperability or the method of treatment of McWhorter, of Edinburgh, we are probably going to allow some of these patients to die who could be salvaged. Rienhoff, in a discussion in a recent *Annals of Surgery*, reported cases which would not have been saved had he followed Haagensen and Stout's criteria of inoperability.

In the first case shown, with the large ulcerating carcinoma, we began to do a palliative procedure in order to free the patient of the odor and the frequent dressing which were such a problem. After the axilla was approached a frozen section of one of the enlarged nodes was studied, and it showed only an inflammatory process. For this reason, the remaining nodes of the axilla were resected, all of them showing only an inflammatory process. It is quite likely that the patient

will have a recurrence, but at the present time the patient is living, comfortable and very happy about the fact that she is now free from the smelly mass on her chest.

In regard to the section of the axilla in cases of the transverse incision in the axilla, such as the modified Rodman incision, we have had no difficulty in cleaning the axilla well.

Dr. William E. Leighton, St. Louis: In the 105 cases mentioned there were no swollen arms and there was recurrence in the skin in only 1 case. That was possibly a badly selected case, because the growth was more or less ulcerating in the upper outer quadrant, and I am afraid that we did not make a wide enough skin incision. The principle on which we determine the amount of skin to be removed—that the skin margin should be at least 2 inches (5 cm.) from the border of the tumor—is more or less generally accepted.

EFFECTS OF SYMPATHECTOMY ON THE CEREBRAL CIRCULATION OF HYPERTENSIVE PATIENTS

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WE HAVE previously shown that the cerebral circulation participates in the generalized increase in vascular resistance that characterizes human hypertension.[1] The beneficial effects of surgical procedures on the sympathetic nervous system in the amelioration of the increased vascular resistance include evidence that perhaps the cerebrovascular resistance is also affected. Such evidence consists of relief from the cerebral symptoms of hypertension and the improvement in the hypertensive eyeground changes.

In an effort to determine more precisely the effects of the surgical treatment of hypertension on the cerebral circulation, we have measured the cerebral blood flow, cerebrovascular resistance and cerebral oxygen consumption in a series of patients before and after standard operative procedure performed for the relief of hypertension.

METHODS

The cerebral blood flow of patients with essential hypertension judged suitable for sympathectomy was determined by the nitrous oxide method[2] a few days before operation. Mean arterial pressure was obtained with a damped mercury manometer attached to a needle in the femoral artery. Analyses of blood gas were made with the Van Slyke-Neill manometric apparatus. The cerebral oxygen consumption and the cerebrovascular resistance of these patients were calculated as previously described.[2]

Aided by a grant from the Public Health Service.

From the Graduate Hospital of the Graduate School of Medicine, the Harrison Department of Surgical Research, and the Department of Medicine, School of Medicine, University of Pennsylvania.

1. Kety, S. S.; Hafkenschiel, J. H.; Jeffers, W. A.; Leopold, I. H., and Shenkin, H. A.: The Blood Flow, Vascular Resistance, and Oxygen Consumption of the Brain in Essential Hypertension, J. Clin. Investigation **27**:511, 1948.

2. Kety, S. S., and Schmidt, C. F.: The Nitrous Oxide Method for the Quantitative Determination of Cerebral Blood Flow in Man: Theory, Procedure, and Normal Values, J. Clin. Investigation **27**:476, 1948.

Bilateral lower thoracic sympathectomy (ninth to twelfth thoracic nerve) and splanchnicectomy were performed in 5 patients. Bilateral thoracolumbar sympathectomy (fifth or eighth thoracic to second or third lumbar nerve) and splanchnicectomy were carried out in 4 patients.

The cerebral circulatory studies mentioned were repeated three weeks to six months after operations, when the patients were ambulatory and ready for discharge, or after discharge, from the hospital.

RESULTS

The table summarizes all the data collected. Of the 9 patients studied, a reduction in mean arterial blood pressure occurred in 7 after operation. In these 7 patients the average fall in mean arterial pressure was 27 mm. of mercury, with a range of 11 to 71 mm. The mean fall in blood pressure when the entire group of 9 patients is considered was 20 mm. (13 per cent), statistically a significant change (the value for p being 0.02).

The cerebral blood flow and cerebral oxygen consumption remained constant after operation. However, the cerebrovascular resistance was distinctly affected, being reduced in 8 of the 9 patients. The reduction in cerebrovascular resistance averaged 18 per cent (p less than 0.02).

The only other real change noted after operation was an almost constant fall averaging 1.5 volumes per cent (p less than 0.01) in the oxygen content of both the arterial and the internal jugular blood.

COMMENT

These studies reveal a distinct decrease in the impedance to blood flow through the brain in essential hypertension as a result of bilateral splanchnicectomy plus lower thoracic sympathectomy or lower thoracic and lumbar sympathectomy. Since the operation in no instance involved denervation of the cerebral vessels, another mechanism for the reduction of the cerebrovascular resistance must be presumed.

It will be noted that a significant reduction of arterial oxygen content occurred after operation. Figure 1, however, reveals only a poor correlation (p greater than 0.1) between the arterial oxygen content and the cerebrovascular resistance before and after operation. Nevertheless the significant reduction postoperatively of the arterial oxygen content does reflect a relative anemia that could be related to a reduced blood viscosity, which in turn, if it had been measured, could be a significant factor in the postoperative reduction of cerebrovascular resistance.

On the other hand, a very high degree of correlation (p less than 0.001) exists between the mean arterial pressure and cerebrovascular resistance preoperatively and postoperatively (fig. 2). It may be that the generalized vasoconstriction, including the cerebral vessels, in hypertension is the result of pressor substances in the general circulation. The favorable effects of operation in reducing the production or effective-

Blood Gases and Cerebral Circulatory Functions Before and After Sympathectomy on Patients with Hypertension †

Patient	Age	Arterial Blood: CO_2 Content, Volumes %		Arterial Blood: O_2 Content, Volumes %		Internal Jugular Blood: CO_2 Content, Volumes %		Internal Jugular Blood: O_2 Content, Volumes %		Arteriovenous Oxygen, Volumes %		Respiratory Quotient		Cerebral Blood Flow, Cc./100 Gm./Minute		Cerebral Oxygen Consumption, Cc./100 Gm./Minute		Cerebrovascular Resistance, Mm. Hg./Cc./100 Gm./Minute		Mean Arterial Pressure, Mm. Hg.		Operation, Resection of Bilateral Splanchnic Nerves Plus
		C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	
A. R.	33	44.1	45.8	18.5	15.3	52.7	51.0	9.6	8.6	8.9	6.7	0.97	0.78	51	50	4.5	3.4	2.6	2.2	130	108	T5 to L3
L. A.	47	43.9	43.9	19.2	19.2	51.8	52.8	10.7	10.2	8.5	9.0	0.93	0.99	51	46	4.2	4.1	2.3	2.1	119	98	T9 to T12
M. S.	51	48.5	53.4	13.6	10.2	52.7	56.1	9.0	5.9	4.6	4.3	0.91	0.63	63	56	2.9	2.4	2.6	1.6	163	92	T9 to T12
E. A.	43	52.1	54.4	15.1	11.2	57.6	56.6	9.4	7.2	5.7	4.0	0.97	0.75	69	66	3.1	2.6	2.3	2.0	158	135	T9 to T12
M. O.	40	44.2	47.7	17.5	16.5	49.5	54.6	10.5	8.7	7.0	7.8	0.77	0.90	54	49	3.8	3.3	3.5	3.4	190	168	T8 to L2
J. M.	48	56.8	48.9	15.8	15.1	62.1	56.6	8.5	7.8	7.3	7.3	0.73	0.95	45	71	3.3	5.5	3.7	2.5	168	179	T8 to L2
L. T.	42	49.9	45.4	17.6	16.6	55.4	52.9	11.4	9.3	6.2	7.3	0.89	1.02	55	50	3.4	3.7	2.5	2.8	137	138	T5 to L3
A. A.	44	50.6	51.0	15.2	14.0	56.5	55.9	9.8	8.8	5.4	5.6	1.09	0.94	49	51	2.6	2.7	2.3	2.3	159	141	T9 to T12
Y. J.	46	53.7	51.8	16.4	15.6	58.5	56.5	10.8	10.9	5.6	4.7	0.86	1.00	57	72	3.2	3.4	2.4	1.7	134	123	T5 to L3
Mean	44	49.3	49.1	16.5	14.9*	55.2	54.8	10.0	8.6*	6.6	6.3	0.90	0.86	55	57	3.5	3.5	2.8	2.3*	151	131*	

* This denotes significant change ($p<0.02$).
† C indicates control study and P postoperative study.

ness of such substances would cause a reduction of cerebrovascular resistance *pari passu* with the lowering of arterial pressure. However, the role of such pressor substances remains to be clarified in regard to human hypertension.

A hypothesis worthy of consideration is that there is an intrinsic mechanism which adjusts the cerebrovascular resistance to alterations

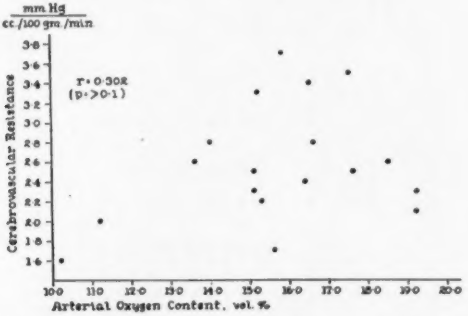

Fig. 1.—Relationships of cerebrovascular resistance to arterial oxygen content before and after sympathectomy for hypertension.

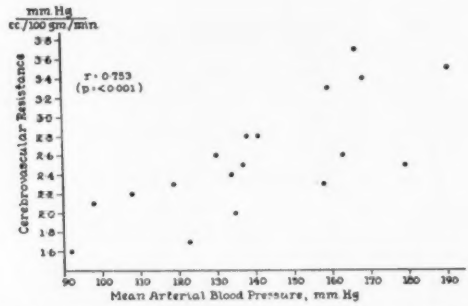

Fig. 2.—Relationship of cerebrovascular resistance to mean arterial blood pressure before and after sympathectomy for hypertension.

of perfusion pressure (mean arterial blood pressure) and thus maintains the cerebral blood flow at a normal level. One possibility for such intrinsic control of the cerebral circulation would be via the carotid sinus mechanism. Thus the intracarotid pressure, participating in the general decrease in mean arterial pressure due to the reduction of peripheral resistance resulting from denervation of the large splanchnic

bed, would be lowered. This alters the stimulus to the carotid sinus which could result in a relaxation of the cerebral vasoconstriction. This theory would well explain the excellent correlation of the reduction in cerebrovascular resistance with the observed lowering of the mean arterial pressure after operation (fig. 2).

These findings may be contrasted with the results of a study of the acute effects of differential spinal sympathetic block in a similar group of hypertensive patients.[3] In that study a 27 per cent fall in mean arterial blood pressure was accompanied with a reduction in cerebrovascular resistance of only 16 per cent resulting in a significant fall in cerebral blood flow to the extent of 12 per cent. In the present series the cerebral blood flow shows no change after sympathectomy even though the mean arterial blood pressure was reduced by 13 per cent. A number of reasons suggest themselves in explanation of this difference. There is evidence of significant hemodilution in the studies after sympathectomy in contrast to a negligible fall in arterial oxygen content in the studies during sympathetic block, indicating a decreased viscosity in the former series after sympathectomy. Secondly, the acute effects of sympathetic block included some degree of hyperventilation and a resultant small change in arterial carbon dioxide in such a direction as to maintain a higher cerebrovascular resistance.[4] There is, in addition, the element of time. Whereas the studies of sympathetic block were made within a few minutes of the hypotensive effect, the studies after sympathectomy were made at least three weeks after operation, by which time many, if not all, compensatory adjustments may have occurred.

We have previously shown that the degree of retinal changes occurring in hypertensive patients correlated well with the increase observed during cerebrovascular resistance.[5] It is a common experience to note improvement in the retinal picture following operation, and several unequivocal reports on this subject have appeared in the literature.[6]

3. Kety, S. S.; Hafkenschiel, J. H.; King, B. D.; Horvath, S. M., and Jeffers, W. A.: The Effect of Differential Thoracolumbar Spinal Sympathetic Block on the Cerebral Circulation of Hypertensive Patients, to be published.

4. Kety, S. S., and Schmidt, C. F.: The Effects of Active and Passive Hyperventilation on Cerebral Blood Flow, Cerebral Oxygen Consumption, Cardiac Output and Blood Pressure of Normal Young Men, J. Clin. Investigation **25**:107, 1946.

5. Leopold, I. H.; Kety, S. S.; Jeffers, W. A.; Hafkenschiel, J. H., and Shenkin, H. A.: Correlation of the Cerebrovascular Resistance and the Grade of Hypertensive Retinal Findings, Am. J. Ophth. **32**:365, 1949.

6. Smithwick, R. H.: Surgical Treatment of Hypertension: Effect of Radical (Lumbodorsal) Splanchnicectomy on the Hypertensive State of Patients Followed One to Five Years, Arch. Surg. **49**:180 (Sept.) 1944. Peet, M. M., and Isberg, E. M.: The Surgical Treatment of Arterial Hypertension, J. A. M. A. **130**:467 (Feb. 23) 1946.

Our present data demonstrating a reduction of cerebrovascular resistance following such operative procedures well explain this improvement in the optic fundi and confirm our original observation on this relationship.

A most important conclusion from this study is that the increased cerebrovascular resistance present in hypertension is not a fixed condition and that a reduction of blood pressure resulting from sympathectomy does not reduce the cerebral blood flow.

SUMMARY

In a series of 9 patients studied before and after sympathectomy for essential hypertension, a distinct fall in cerebrovascular resistance was found to occur postoperatively. This decrease in cerebrovascular resistance permitted the cerebral blood flow to be maintained at normal levels despite the decrease in mean arterial blood pressure which resulted from operation.

It is suggested that this observed decrease of the cerebrovascular resistance in cases of essential hypertension treated surgically might well explain the beneficial effects of operation on the cerebral symptoms and retinal changes of hypertension.

The possible mechanism responsible for this reduction of cerebrovascular resistance is discussed.

IRRADIATION NECROSIS OF THE HEAD OF THE FEMUR

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AND

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WITH THE increasing frequency of the use of high voltage roentgen rays in the treatment of malignant neoplasms, the effects on normal tissue have become increasingly important to the radiotherapist and to the clinician. Not the least important of these effects are the changes occurring in bone and cartilage, although they do not appear to be widely familiar from a clinical point of view. Nevertheless, changes occurring in bone as a result of irradiation therapy have been reported since 1903, and in this paper we wish to review briefly the pathologic process involved and to present 2 cases, 1 of which is the third to be reported involving a male patient, as examples of the pathologic and the clinical importance of postirradiation lesions.

Wammock and Arbuckle [1] quoted Perthes, who described the effects of roentgen rays on epiphysial growth in 1903, and Cluzet, who in 1910 described delay in callus formation occurring as a result of irradiation of bone.

Attention to the pathologic effects of irradiation of bone was not sharply focused until 1926, when Ewing [2] reviewed the effects of irradiation on the tissues and described in detail its effects on bone. He emphasized that tissues irradiated in vivo behave differently from those irradiated in vitro, the changes in the blood vessels being especially significant. The blood vessels are closed, the fine ones first and then the larger ones. This requires time after the initial dose has been given, which varies with the hardness of the rays and the mildness of the dose. Ewing ascribed the effect of irradiation on bone to interference with its nutrition which is a result of obliteration of the

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1. Wammock, H., and Arbuckle, R. K.: Fractures of the Rib Cage Following Interstitial Radium Therapy for Cancer of the Breast, Am. J. Roentgenol. **50**:609-615 (Nov.) 1943.

2. Ewing, J.: Tissue Reactions to Radiation, Am. J. Roentgenol. **15**:93-115 (Feb.) 1926.

vascular supply from the periosteum, the nutrient artery, capsular arteries and the bone marrow and to secondary irradiation due to the high calcium content.

In 1927 Baensch [3] published the first recorded case of spontaneous fracture of the neck of the femur occurring after pelvic irradiation. After this, case reports were published by Baensch in 1932, Philipp in 1932 [4] and Kropp in 1934,[5] but no extensive series was presented until Dalby, Jacox and Miller in 1936 [6] reported 14 cases of fracture of the femoral neck following irradiation of the pelvis, with an incidence of 2.1 per cent. Their cases involved women who had received irradiation therapy for neoplasms involving the cervix and fundus uteri, the ovary and the vulva. The average age of the patients was 57 years, extremes being 42 and 78 years. Fracture was spontaneous. Actual fracture was preceded by a history of several months (average, seven) of pain in the hip, radiating to the anterior part of the thigh down to the knee. The pain was aggravated by weight bearing or motion. The average lapse of time from diagnosis of the neoplasm to the time of fracture was three years (extremes, nineteen to seventy-three months). The question of the fracture's being due to metastasis to the neck of the femur was discussed, and none of their patients showed metastasis at the site of fracture. In 9 patients fibrous union developed, while none showed callus formation at ten months after fracture or later. The authors stated that the fracture began in the superior portion of the femoral neck close to the head. Ten of their patients were given extensive irradiation, while 4 in the older age group had a small total dose.

They described the microscopic changes found in 1 case. The blood vessels of the ligamentum teres were sclerosed. The synovium showed productive inflammatory foreign body reaction around fragments of absorbing bone. Rarefying osteitis, osteoporosis, absorption of bone, a foreign body inflammatory reaction and local new formation of cartilage and bone completed the picture, which is that of progressive bone absorption and fibrosis.

In 1938 Miller and Folsome [7] added 21 cases to this series, making a total of 35 proved and "many more probable fractures."

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3. Baensch, W., cited by Gratzek, Holmstrom and Rigler.[18]

4. Philipp, E., cited by Dalby, Jacox and Miller.[6] Philipp, E., cited by Strauss and McGoldrick.[9]

5. Kropp, L., cited by Dalby, Jacox and Miller.[6] Kropp, cited by Strauss and McGoldrick.[9]

6. Dalby, R. G.; Jacox, H. W., and N. F. Miller, abstracted, Fracture of the Femoral Neck Following Irradiation, Am. J. Obst. & Gynec. **32**:50-59 (July) 1936.

7. Miller, N. F., and Folsome, C. E.: Carcinoma of the Cervix, Am. J. Obst. & Gynec. **36**:545-561 (Oct.) 1938.

In 1939 Okrainetz and Biller [8] reported a case of spontaneous fracture of the neck of the femur occurring after irradiation for ovarian cancer. They emphasized the danger of assuming the existence of skeletal metastasis in a bone which has been heavily irradiated on the basis of pain alone without adequate roentgenologic evidence. They mentioned the occurrence of arthritic changes in the hip joint and bony absorption of the head of the femur. Fracture occurred three years after the initial irradiation, and the patient died two years later. Microscopic examination of the neck of the femur showed acellular necrotic debris, fibrosis, hyalinization and obliterative endarteritis.

Strauss and McGoldrick in 1941 [9] presented 4 new cases of fracture of the femoral neck. Their conclusions were that the use of lateral ports in pelvic irradiation was not justified, that there was a definite cumulative action of roentgen rays on bone and that the vascular supply to the bone was most important. Poor nourishment, with a possible calcium-phosphorus imbalance, was a factor to be considered. Microscopic examination in 1 of their cases showed the following: (1) the cortex was absent and replaced by poorly cellular fibrous tissue; (2) trabeculae were small and decalcified; (3) no new bone formation was present; (4) the marrow was fatty; (5) the periosteum was thick, dense, fibrous and relatively acellular; (6) no osteoblasts were seen; (7) marked thickening of the subintimal layer of arteries was present, and (8) arteries in the ligamentum teres were thickened and some occlusion was present.

Hight [10] and Baker [11] each reported 1 case of irradiation fracture of the neck of the femur, Hight's case involving a man who received irradiation for carcinoma of the penis.

In 1943 Wammock and Arbuckle,[1] discussing spontaneous rib fractures occurring after irradiation for cancer of the breast, described the changes as a degeneration of the blood vessels in the haversian systems, the ground substance showing eosinophilic lines and streaks and the bone cells being granular, many with no nuclei. Blood vessels in the fat were few and hyaline, and no hemopoietic tissue was seen.

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8. Okrainetz, C. L., and Biller, S. B.: Fracture of the Neck of the Femur Complicating Roentgen Therapy of Ovarian Cancer, Am. J. Roentgenol. **42**:883-887 (Dec.) 1939.

9. Strauss, H., and McGoldrick, J. L.: Fracture of the Femoral Neck Following Roentgen Therapy for Gynecological Malignancy, Am. J. Obst. & Gynec. **41**:915-933 (June) 1941.

10. Hight, D.: Spontaneous Fracture of the Femoral Neck Following Roentgen Ray Therapy Over the Pelvis, J. Bone & Joint Surg. **23**:676 (July) 1941.

11. Baker, L. D.: Spontaneous Fracture of the Femoral Neck Following Irradiation, J. Bone & Joint Surg. **23**:354-358 (April) 1941

Friedmann,[12] in considering the same subject, described the bone as the seat of a progressive fibrosclerosis.

Slaughter,[13] in a review of osteitis and fractures following irradiation, stated that irradiation increases the delay in the reparative reaction of bone by the production of an obliterative endarteritis. The structural changes seen do not appear as a single typical picture but vary from periosteal thickening with fibrosis and hyalinization, fat replacement and fibrosis of the marrow to aseptic necrosis. Sequestrums, fragmentary or massive, may exist for years, as there is interference with the normal creeping substitution of bone because of obliteration of the vascular supply. He emphasized the frequency of changes when weight bearing was present and the blood supply precarious.

In 1943 Gates[14] described her conclusions from experiments in the irradiation of bone in animals as follows: 1. Retardation or cessation of bone growth occurs if the dose is above the tolerance threshold. 2. Fractionation of dose and protraction of intervals enhance the effect. 3. Phosphatase is decreased, the maximum decrease occurring in one to three weeks, with recovery in four to five weeks. 4. The contour of the bone remains normal—if there is any alteration, it depends on muscle strength and unequal trauma to the bone. 5. The earliest histologic changes in animals are (*a*) early alteration of cartilage cells, i. e., swelling, pyknosis and loss of columnar pattern, and (*b*) disorientation of the enchondral ossification pattern and coarsening and loss of fibrils in the matrix. In the epiphysial cartilage the cells may regain some degree of recovery, but enchondral ossification is disturbed and a brittle thick callus is formed.

Gates also stated that enchondral and periosteal ossification are of the same radiosensitivity (Dahl) while osteoblasts are less sensitive. After irradiation the normal rhythm of bone formation and resorption is lost. The results of irradiation of healing bone are not uniform. Healing is probably delayed, with the production of a small callus which is slow in becoming rigid, and Gates emphasized the importance of the phosphatase changes in connection with this. She described the effects of irradiation on hyaline cartilage as being less marked than those on epiphysial cartilage, with the late production of perichondritis, and mentioned that hyaline cartilage withstands a large amount of irradiation as long as it is protected from infection and trauma.

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12. Friedmann, A. B.: Spontaneous Rib Fractures Following Irradiation for Cancer of the Breast, Am. J. Roentgenol. **50**:797-800 (Dec.) 1943.

13. Slaughter, D. P.: Radiation Osteitis and Fractures Following Irradiation, Am. J. Roentgenol. **48**:201-212 (Aug.) 1942.

14. Gates, O.: Effects of Irradiation on Bone, Cartilage and Teeth, Arch. Path. **35**:323-339 (Feb.) 1943.

Barden in 1943 [15] and Heyman in 1945 [16] each reported a case of bilateral fracture of the femoral neck following irradiation.

Smithers and Rhys-Lewis in 1945 [17] reported the second case of fracture of the neck of the femur following irradiation in a male patient. Their patient was 56 years old and received 4,800 r to the groin during treatment for a fibrosarcoma of the thigh. Three months after irradiation he complained of pain, and a roentgenogram showed no abnormality in the femur. Three months after his complaints began a repeated roentgen examination showed a fracture of the femoral neck.

In 1946 Gratzek, Holmstrom and Rigler [18] discussed postirradiation bone changes and reviewed a series of 1,904 patients from July 1926 to December 1942, in which there were 25 instances of bone necrosis or spontaneous fracture of bones in 19 patients. They stated that 3.2 per cent of women with pelvic cancer who receive pelvic irradiation can be expected to show degenerative changes in the femur. Among 541 men who received irradiation for neoplasm of the bladder or prostate, no spontaneous fractures appeared. They stated that irradiation showed its effects in bone in the form of retardation of growth, due mainly to circulatory changes, widening and irregularity of the lacunas and loss of lamellar structure. There is a marked resemblance to the changes seen in cases of osteochondrosis, post-traumatic aseptic necrosis and caisson disease, which bears out their common vascular origin. The authors discussed factors contributing to the bone changes and noted that the incidence of spontaneous fracture is greater after more intensive therapy. Treatment depends on the extent of the pathologic condition, and Gratzek, Holmstrom and Rigler advocated McMurray osteotomy in the presence of fracture and necrosis. They stated that impending fracture can be predicted from sclerotic changes seen in the femoral neck, i. e., (1) an area of increased density, (2) transverse lines of density across the femoral neck, occasionally with areas of rarefaction, and (3) changes in the head—there is slight increase in density and then details of trabeculae are lost and areas of rarefaction are seen.

In 1946 Spear [19] described the effects of irradiation under two headings—the direct effect on the tissue cell and interference with cell

15. Barden, S. P.: Healing of Radiation Fracture of the Necks of the Femora, with a Report of a Case, Radiology **41**:389-394 (Oct.) 1943.

16. Heyman, C. H.: Spontaneous Bilateral Fracture of the Neck of the Femur Following Irradiation, J. Bone & Joint Surg. **27**:674-678 (Oct.) 1945.

17. Smithers, D. W., and Rhys-Lewis, R. D. S.: Bone Destruction in Cases of Carcinoma of the Uterus, Brit. J. Radiol. **18**:359 (Nov.) 1945.

18. Gratzek, F. R.; Holmstrom, E. G., and Rigler, L. G.: Post Irradiation Bone Changes, Am. J. Roentgenol. **53**:62-76 (Jan.) 1945.

19. Spear, F. G.: The Biological Effects of Penetrating Radiation, Brit. M. Bull. **4**:2-11, 1946.

proliferation plus injury to neighboring tissue on which the cell depends, the latter being mainly due to interference with the blood supply to the part.

Stampfli and Kerr,[20] presented a series of 14 radiation fractures of the neck of the femur, subcapital in situation, in 1947. They stated that fracture of the femoral neck is the most common skeletal injury secondary to irradiation. Their 14 cases occurred in a series of 1,372 female patients who received pelvic irradiation. Twelve of the fractures were spontaneous, and for two there was a history of trauma. Four patients had bilateral fractures. The average age of the patients was 56 years, compared with the average age of 60 to 65 for all fractures of the femoral neck. Pain often preceded the fracture by months. The first roentgenologic sign of fracture was subcapital mottling, and a zone of sclerosis formed across the neck of the femur. They stated that complete fracture may not occur but that coxa vara due to bending may result. In view of the possibility of aseptic necrosis of the head of the femur, they recommended a subtrochanteric osteotomy for the treatment of these patients.

Woodard and Coley [21] described overirradiation as destroying the regenerative power of bone, biopsy showing no viable bone cells and radiation fibrosis of adjacent soft parts, with impairment of blood supply to the bone. Young bone appears to be more resistant than adult bone.

REPORT OF CASES

Case 1.—The patient, a man aged 37 years, was first admitted to Deer Lodge Hospital on Aug. 18, 1944, at which time he was complaining of an enlargement of the left side of the scrotum, which he first noticed in July 1944. There were no other complaints. The past history was irrelevant except that gonorrhea was present in 1940 and was treated, with apparent cure.

The mass in the left side of the scrotum was removed on Aug. 23, 1944, and the pathologic examination showed it to be a teratoma of the left testis. The patient made an uneventful recovery and was discharged, to receive a course of high voltage roentgen ray therapy.

He received four courses of irradiation, in October 1944, January 1945, August 1945 and March 1946. Each course consisted of treating the halves of the pelvis, front and back, and the left half of the abdomen with 1,170 r in one month. A 200 kilovolt therapy unit was used, with 20 milliamperes, 1 mm. aluminum and 2 mm. copper, for ten minutes per day and 130 r per port. After completion of this treatment he was admitted to the hospital on June 24, 1946, for investigation of symptoms which were diagnosed as effects of irradiation on the bowel. Investigation showed no sign of recurrence of his original tumor.

In January 1947 he complained of pain in the left groin for three weeks, which was burning in nature and aggravated by walking and which increased in severity.

20. Stampfli, W. P., and Kerr, H. D.: Fractures of the Femoral Neck Following Pelvic Irradiation, Am. J. Roentgenol. **57**:71-83 (Jan.) 1947.

21. Woodard, H. Q., and Coley, B. L.: The Correlation of Tissue Dose and Clinical Response in Irradiation of Bone Tumors and of Normal Bone, Am. J. Roentgenol. **57**:464-471 (April) 1947.

There was tenderness along the iliopsoas muscle; pain was produced on hip flexion and slightly on adduction. Roentgenograms of the hip were normal (fig. 1). Investigation showed no sign of recurrence, but a further course of irradiation was advised by a surgical consultant in view of the fact that the pain was possibly due to retroperitoneal metastasis. This was given in January 1947, the left half of the pelvis, front and back, and the back of the lumbar region receiving a total of 1,200 r in one month.

After this he had a severe bout of irradiation sickness but was later able to return to work.

He was admitted to the hospital on April 20, 1948, when his complaints were pain in the left groin, aching in nature and aggravated by excessive movement, walking and bending, and weakness of the left leg. Physical examination showed slight shortening of the left leg and atrophy of the left thigh, with limitation of

Fig. 1.—Roentgenogram taken on Jan. 8, 1947, shortly after the onset of symptoms. No significant changes are present.

internal rotation and abduction of the left hip. A roentgenogram of the left hip showed osteoporosis of the bones, some narrowing of the joint space and a subcapital area of rarefaction with slight flattening of the head of the femur (fig. 2). Early osteoarthritis of the left hip was diagnosed, and lighter work was advised. If this failed to secure relief, an arthroplasty was to be considered.

The pain continued to increase in severity, and the patient became incapacitated, lost weight and was unable to sleep at night.

A roentgenogram of the left hip in August 1948 showed further narrowing of the joint space, with sclerotic changes in the head and neck of the femur, a transverse line of density crossing the neck of the femur in the subcapital region, increased flattening of the femoral head and a cystic appearance of the adjacent ilium (fig. 3). Serum calcium and phosphorus, acid and alkaline phosphatase were within normal limits.

Fig. 2.—Roentgenogram taken on April 23, 1948, approximately sixteen months after the onset of symptoms, showing osteoporosis, some narrowing of the joint space, a subcapital area of rarefaction and slight flattening of the head of the femur.

Fig. 3.—Roentgenogram taken on Aug. 11, 1948, showing further flattening of the head of the femur, mottling of the head, a line of increased density crossing the neck of the femur in the subcapital region and a cystic appearance of the adjacent ilium.

When the patient was admitted for arthroplasty on Oct. 18, 1948, there was a half inch (1.27 cm.) shortening of the left leg, one and a half inch (3.8 cm.) atrophy of the left thigh, half inch (1.27 cm.) atrophy of the left calf, flattening of the left buttock and marked limitation of flexion and abduction of the left hip. Laboratory findings were normal.

Arthroplasty was carried out on Nov. 3, 1948, a modified Kocher approach being used. When the capsule of the joint was excised, it was found to be tremendously thickened, and, when opened, the joint was found to be distended with

Fig. 4.—Section of the labrum glenoidale illustrating infiltration with lymphocytes and plasmocytes and thickening of the arterial walls with palisading of endothelial cells. Tissue is acidophilic.

blood-tinged serous fluid. The head of the femur was dislocated and was found to be markedly deformed, and the superior portion of the head was soft, rubbery and easily compressible. This was a most impressive feature of the operation—the head of the femur could be easily indented with a blunt instrument and sprang back to its previous shape on release of the pressure. The necrotic portion of the head separated easily, and a clear line of vascular granulation tissue demarcated the necrotic portion from that still living. The necrotic portion was avascular,

soft and compressible and formed the greater part of the head of the femur. A vitallium® cup was fitted over the stump of the femur and the dislocation reduced. Material for biopsy was taken from the skin, muscle and structures of the hip joint.

The pathologic report was as follows:

Gluteus medius muscle. The section shows, in a few areas, infiltration of capillary walls and immediate surroundings by polymorphonuclear leukocytes (minimal).

Fig. 5.—Section of ligamentum teres, to illustrate particularly endarteritis in an artery with marked narrowing of the lumen and thickening of the arterial wall. There is thickening of the walls of the smaller vessels, with focal areas of round cell infiltration.

Joint capsule. Some arterioles show complete obliteration and others reduction of lumen by fibrous thickening of the walls. There is collagenous eosinophilic staining.

Skin over groin. A thin squamous epithelial layer is present. There is considerable collagenous tissue in the cutis vera replacing normal areolar type of tissue.

Synovial membrane. Endarteritis obliterans with palisade arrangement of endothelial cells is seen. There is some vacuolation in vessel walls.

Labrum glenoidale. The arterial walls are thickened, with a palisade arrangement of endothelial cells. There are scattered areas of infiltration by lymphocytes and plasmocytes and some vacuolation of the subintima of arterioles. The tissue appears acidophilic (fig. 4).

Ligamentum teres. Endarteritis of small vessels is prominent, with some vessels entirely closed. There are areas of infiltration by lymphocytes and plasmocytes (fig. 5).

Fig. 6.—Section of articular cartilage from head of femur, to show mucinous degeneration of cartilage, death of cartilage cells, subchondral granular degeneration without cellular structure and amorphous degeneration of the articular surface of the cartilage.

Cartilage from head of femur. There are deep pink granular areas of degeneration of cartilage having no cellular structure. Other areas appear mucinous. There is disorderly arrangement of the osseochondral line and enchondral ossification, and there is irregular eroded cancellous bone (fig. 6).

Bone from head of femur. Cancellous bone with fatty marrow spaces some of which show that fibrosis is present. Some arterioles show endarteritis. Bone

trabeculae appear thinned, and the cement line pattern in bone is accentuated. Some trabeculae appear eroded. Osteoblasts are absent (figs. 7 and 8).

After operation the patient's convalescence was uneventful, being characterized only by his rapid response to active exercise, so that at the end of six weeks he had regained 130 degrees active flexion of the left hip, approximately 30 degrees of abduction and good combined flexion, external rotation and abduction, and he was able to place the left heel on the front of the right thigh 6 inches (15.24 cm.) above the knee.

Fig. 7.—Section of cartilage and bone from the head of the femur. Erosion of bone, accentuation of the cement line pattern in the bone, a disordered osseochondral line, death of cartilage cells and amorphous degeneration of cartilage and fibrosis are seen.

CASE 2.—The patient, Mrs. J. E. aged 56, first consulted a gynecologist on Jan. 1, 1947, complaining of vaginal bleeding. She had no other complaints. On examination the cervix appeared normal, but biopsy of the material from the posterior lip showed a squamous, keratinizing, infiltrating, epidermoid carcinoma, grade 2.

On Feb. 10, 1947, she received 3,600 mg. hours of irradiation by means of radium pack, and on February 28 she received 2,400 mg. hours of irradiation by means of radium bomb. From February 12 to April 17 she received 11,600 r units by means of high voltage therapy, six ports being used.

After this her pelvis remained clear, and the cervix now appears normal. There has been no sign of recurrence of carcinoma.

Fig. 8.—Section of bone from the head of the femur. Erosion of trabeculae, accentuation of the cement line pattern, empty lacunae and fibrosis in the fatty marrow with areas of amorphous degeneration are seen. The blood vessels show endarteritis obliterans, and there is scattered round cell infiltration.

On Oct. 29, 1948, she complained of a limp and of aching pain in the right hip, present for two and a half months. There was some limitation of movement in the right hip, and a roentgenogram showed a zone of rarefaction and sclerosis in the subcapital region of the neck of the right femur, extending across it (fig. 9 *A*).

She was placed on a regimen of limited activity, but weight bearing was not forbidden. During the winter of 1948-1949 she continued with her activities but

rested considerably. Her complaints of aching pain continued. Reexamination in March 1949 revealed limitation of movement in the right hip, and a roentgenogram showed a definite subcapital fracture of the neck of the femur (fig. 9 *B*).

Fig. 9.—*A*, roentgenogram in case 2 taken on Oct. 29, 1948, showing the subcapital zone of rarefaction and sclerosis, indicative of impending fracture. *B*, roentgenogram in case 2 taken on March 3, 1949, showing the complete subcapital fracture of the femoral neck which has occurred along the line of the previously visible area of sclerosis and rarefaction.

Treatment with a vitallium® cup is being considered, as pain is the patient's main symptom, and the range of movement will very likely be better with a vitallium® cup than with a McMurray osteotomy.

COMMENT

We consider both these cases to be excellent examples of irradiation injury to bone and cartilage. Case 1 exhibited the injury clinically as rapidly progressing arthritis of the hip joint and pathologically as a sterile necrosis of bone and cartilage due to vascular obliteration, while case 2 followed the more usual pattern of necrosis and subcapital fracture of the femoral neck.

Clinically, our patients present several features of interest, which corroborate many of the findings in the reported cases of irradiation injury to the head and neck of the femur.

The age of our male patient at the time of onset of his symptoms referable to the left hip was 40, and the time of onset was approximately two years and three months after the first course of roentgen ray therapy was given. The interval of time from the onset of symptoms to the demonstration of gross clinical signs indicating disease of the left hip joint was approximately one and a half years, and at that time roentgenologic changes in the joint and the head and neck of the femur were minimal.

The age of our female patient was 56 years, and her first symptoms appeared one year and four months after her course of irradiation. A definite fracture was apparent two years after irradiation.

The rapid progression of clinical signs, symptoms and roentgenologic changes in the patient in case 1 is characteristic of the influence of weight bearing as a traumatic factor in the presence of a massive necrosis of the head of the femur. His work may have precipitated an earlier onset of arthritis than would have occurred in a sedentary worker, as it involved jumping on and off moving trains and thus constituted a relatively severe source of trauma. Phemister [22] emphasized the importance of the involvement of the weight-bearing portion of the head of the femur in producing early osteoarthritis of the hip. Arthritis may not occur, and reconstitution of the necrotic area may take place if it lies in a portion of the head remote from weight bearing.

Previous case reports emphasize the duration of symptoms prior to fracture of the neck of the femur, and in the great majority of cases pain precedes fracture and demonstrable roentgenologic changes by several months. In case 1 this interval was longer, case 2 following the usual pattern more closely.

Total dosage of irradiation in our male patient was 4,680 r to the right side of the pelvis and 5,880 r to the left side of the pelvis, administered over a period of two and one-half years. The last course of

22. Phemister, D. B.: Changes in Bones and Joints Resulting from Interruption of Circulation, Arch. Surg. **41**:436-472 (Aug.) 1940; Changes in Bones and Joints Resulting from Interruption of Circulation, Arch. Surg. **41**:1455-1482 (Dec.) 1940.

roentgen ray therapy was administered on the basis of pain as a symptom of possible metastasis and emphasized the point made by Okrainetz and Biller [8] that irradiation should not be carried out unless there is definite evidence of metastasis demonstrable in roentgenograms or clinically. The demonstration of metastasis in bone may be possible only after considerable neoplastic tissue has accumulated and when changes in the bony architecture have occurred. This has been illustrated strikingly by Shackman and Harrison [23] in their article on occult bone metastasis, in which they demonstrated normal roentgenograms of vertebrae in which the marrow spaces were filled with metastatic tissue and there was no change in the bony architecture until the neoplastic tissue had been present for some time. This last course of roentgen therapy was probably unnecessary, in view of the failure to demonstrate metastasis at operation. Whether or not it has any bearing on the occurrence of degenerative changes in the left hip rather than the right is uncertain, although it appears to be true that repeated small courses of irradiation are more likely to damage bone than is one massive dose. In view of the findings of Gratzek, Holmstrom and Rigler [18] that the quantity of irradiation was not the only factor involved in their series with wide variation in total dosage, although changes were more likely to occur after more intensive therapy, this cannot be presumed.

The total dosage in our female patient was 11,600 r administered in one course, and trauma was not excessive at any time.

Dunlap,[24] in his treatise on the physical change induced by irradiation, noted that there is no clinical method of diagnosing the changes in bone until roentgenograms demonstrate them. Case 1 demonstrates this well, in that symptoms were present for a long period before roentgenologic changes appeared and physical signs suggestive of disease in the left hip were present before demonstrable change on roentgenogram.

Prior to the occurrence of fracture of the femoral neck, arthritic changes in the hip of the affected side or the opposite side were seen (Stampfli and Kerr,[20] Okrainetz and Biller [8]). In case 1 changes seen in the roentgenograms were almost entirely confined to the head of the femur and the subcapital region, and the typical changes described by Gratzek, Holmstrom and Rigler [18] as diagnostic of impending fracture of the femoral neck were not present to a distinctive degree, as they were in case 2. Consequently, we considered this patient to have rapidly progressing degenerative arthritis of the hip, probably due to interference with the blood supply of the head of the

23. Shackman, R., and Harrison, C. V.: Occult Bone Metastases, Brit. J. Surg. **35**:385-389 (April) 1948.

24. Dunlap, C. E.: Pathology, edited by W. A. D. Anderson, St. Louis, C. V. Mosby Company, 1948, pp. 175-195.

femur, with resultant collapse of the head. As positive treatment was imperative, the performance of an arthroplasty was considered to be the treatment of choice. This was decided in view of the absence of changes in the neck of the femur on roentgen examination and the fact that he was still a young and active man and that a fusion of the hip would not only incapacitate him greatly but also might not be successful in view of the presumed changes in blood supply of the region. The relief of pain was of paramount necessity and demanded revision of the weight-bearing surfaces of the joint, with the minimum of interference with joint action. The modified Kocher approach to the hip joint was used, as it is routine in our hospital and is considered to provide maximum exposure with a minimum of blood loss and of trauma to tissue. It also afforded an opportunity to obtain a biopsy of all representative tissues in the region in order to study the pathologic effects of irradiation. At operation all necrotic bone was removed, and bleeding living bone was adequately demonstrated before the vitallium cup was fitted. Consequently, the likelihood of remote fracture of the neck of the femur is felt to be slight, but if it should occur, McMurray osteotomy would probably provide a relatively simple and satisfactory solution of the problem without interfering with the arthroplasty. We were also influenced in our choice of treatment by the fact that the involvement of the head of the femur was massive and that conservative treatment while growth of new bone was awaited was out of the question because of the extremely long time that would be required, the fact that the head of the femur was already deformed, and the long period of complete incapacity in a young able-bodied man that this would necessitate.

Pathologically, gross and microscopic findings in case 1 corroborate those demonstrated by the authors referred to in the review of the literature and emphasize the importance of vascular change as the basic cause of the pathologic changes present.

Dunlap [24] made the statement that irradiation injuries have no pathognomonic features which distinguish them but that there is a pattern of changes which is fairly distinctive. From previously published reports, it would appear that these changes are contingent mainly on interference with the blood supply to the part as a result of an obliterative endarteritis plus local effects on the cells proper. Consequently, we should expect an aseptic necrosis of bone, with death of osteoblasts, and replacement of dead bone by the process of creeping substitution as described by Phemister.[22] The term radiation osteitis would appear to be a misnomer, as there is little if any inflammation, and the process is a sterile necrosis. This is well illustrated in the photomicrographs, which show only slight infiltration of tissues with lymphocytes and plasmocytes, except for minimal infiltration with polymorphonuclear leukocytes in the section from the gluteus medius muscle.

Since the process appears to be basically a vascular one, relatively small doses of irradiation are sufficient to initiate it—2,500 to 5,000 r, according to Warren,[25] are sufficient to produce changes in the endothelium of blood vessels. Thus changes in bone and cartilage may be produced indirectly, irradiation effects exerted directly on the osteoblasts being insufficient to kill or severely injure them.

Factors involved which must be considered when discussing dosage are not only the surface dosage but the amount of secondary irradiation arising from the calcium content of the bone, the scatter effect and the amount of the surface dose that penetrates sufficiently to reach the bone. We do not feel competent to discuss this from a technical point of view and only wish to point out the necessity for carefully considering possible bone damage in irradiation over bony structures, particularly those which are essential for support and mobility of the body.

Grossly, the most striking changes in case 1 were the notable thickening of the capsule of the joint and the massive necrosis of the head of the femur, with its peculiar elasticity, which suggests complete loss of normal bony architecture. The distinct, sharply drawn line of vascular granulation tissue separating necrotic from living bone is unusual in irradiation necrosis, according to Dunlap,[24] although Santos [26] illustrated exactly this appearance in discussing necrosis of the head of the femur from traumatic interruption of its blood supply. Replacement of dead bone by living may be presumed as having to proceed from this point. It was apparent that the replacement of such a large mass of dead bone would have consumed a long interval of time, if indeed it could occur. In view of the statement of Slaughter [18] that massive aseptic necrosis may exist for years, due to the interference with the normal creeping substitution of bone seen in irradiation lesions, it is exceedingly likely that the head of the femur would not have become revascularized.

Section of the head of the femur shows endarteritis, with erosion of trabeculae, a fatty marrow and fibrosis—all degenerative changes (figs. 7 and 8). The absence of osteoblasts and the accentuation of the cement line pattern are indicative of the death of bone. No evidence of active inflammation is seen, and the changes are those of an ordinary sterile necrosis.

Gates [14] stated that hyaline cartilage can withstand fairly large doses of irradiation if protected from trauma and infection. In our patient, weight bearing constituted a source of trauma, and microscopic findings

25. Warren, S.: Effects of Radiation on Normal Tissues: I. Introduction, Arch. Path. **34**:443 (Aug.) 1942; IV. The Cardio-Vascular System, ibid. **34**:1070 (Dec.) 1942.

26. Santos, J. V.: Changes in the Head of the Femur after Complete Intracapsular Fracture of the Neck, Arch. Surg. **21**:470 (Sept.) 1930.

showed damage to the hyaline cartilage over the head of the femur which was severe in extent and degree. Phemister [22] stated that articular cartilage in the adult derives most of its nourishment from the underlying bone, and interference with the blood vessels of the bone causes disturbance of nutrition of the cartilage. In the event of collapse due to trauma, or long-standing deprivation of blood supply to the underlying bone, necrosis of the cartilage results and arthritis deformans is an ultimate result. As the photomicrographs of the articular cartilage from the head of the femur show in this case (fig. 6), restitution to normal may be considered impossible, in view of the granular and mucinous degeneration and subchondral hyaline degeneration, with distortion of the osseochondral line.

The statement that endarteritis obliterans is the essential underlying cause of tissue changes seen in irradiation lesions (aside from local changes in cells) receives support from the microscopic findings in the tissues from our patient. Section of the ligamentum teres, joint capsule, synovial membrane, labrum glenoidale, head of the femur and skin all exhibit endarteritis obliterans as a prominent feature. It is impossible to say how much of the change seen occurs as a result of direct effect of roentgen rays on osteoblasts, although the dosage given in this case falls within the limits given by Warren [25] as causing injury to mature bone and cartilage. The changes seen in the blood vessels must be considered to play a major part in the development of the death of bone, and if this is so, changes in bone are most likely to occur where the blood supply is precarious and are most likely to be clinically and roentgenologically demonstrable in sites where the insult of trauma is added to the injury of ischemia. Thus the head and neck of the femur are most vulnerable areas.

The blood supply of the head and neck of the femur regarded as a unit is derived from the nutrient artery of the shaft, the capsular vessels from the medial and lateral circumflex femoral arteries and the arteries of the ligamentum teres. The blood supply of the neck arises from the nutrient artery of the shaft, and the capsular arteries, mainly the posterior one. There is much disagreement in regard to the blood supply of the head and the relative importance of the capsular arteries as compared with the arteries of the ligamentum teres. In an effort to elucidate this problem, Wolcott [27] investigated the blood supply of the head and neck of the femur by injection methods, and more recent work by Cheynel [28] and Tucker [29] has, in the main, corroborated his

27. Wolcott, W. E.: The Evolution of the Circulation in the Developing Femoral Head and Neck, Surg., Gynec. & Obst. **77**:61-68 (July) 1943.

28. Cheynel, J.: Recherches sur la physio-pathologie de la hanche, Rev. d' orthop. **33**:7 1947; Internat. Abstr. Surg. **85**:495-496 (Nov.) 1947.

29. Tucker, F. R.: Arterial Supply to the Femoral Head and its Clinical Importance, J. Bone & Joint Surg. **31**:82-93 (Feb.) 1949.

views. Wolcott found that in 80 per cent of the specimens investigated the ligamentum teres carried at least one major artery which penetrated the head and anastomosed with vessels entering the head through the capsule. In 20 per cent this vessel failed to enter the head and the injection material returned from the fovea via the veins in the ligamentum teres. When the artery penetrated the head, it was sufficient to nourish a large part of it. He found that there were no blood vessels entering the head via the ligamentum teres in children under 10 years of age. He stated that the anastomosis between the vessels of the ligamentum teres and the capsular and nutrient vessels does not occur until ossification of the head is practically complete and that the circulation in the ligamentum teres is a closed one until this anastomosis occurs.

Cheynel [28] confirmed the development of the anastomosis between the vessels of the ligamentum teres and the capsular and nutrient vessels, as did Tucker,[29] who stated that there was an anastomosis of the arteries of the ligamentum teres with the capsular and nutrient arteries in 70 per cent of the adult specimens examined by him.

From the point of view of endarteritis obliterans arising as a result of irradiation, the mean sizes of the capsular and ligamentum teres vessels as cited by Tucker are of interest. The mean size of the artery of the ligamentum teres is given as 0.328 mm. in adults, and mean sizes of the capsular arteries range from 0.250 mm. for the anterior capsular artery to 0.839 mm. for the posterior-superior capsular artery. Thus it is seen that these arteries are small and a moderate degree of endarteritis obliterans is sufficient to narrow their lumens greatly, if not sufficient to obliterate them completely. Irradiation injury differs from a traumatic force, which usually affects only one group of the vessels (according to Tucker, the most important and vulnerable group is the posterior-superior capsular group), by being a diffusely acting agent which affects all vessels and cells within its range. Consequently, there is damage to all the vessels supplying the head and neck of the femur and the degree of vascular obliteration will depend to a large extent on the size of the vessels. Sections of the ligamentum teres in our patient demonstrated actual closure of vessels in the ligament, while there was also complete obliteration of vessels in the capsule of the joint and considerable thickening of vessels in the synovial membrane. In these circumstances, there must have been a severe decrease in the blood supply to the head of the femur, sufficient to cause massive necrosis.

In conclusion, it may be said that case 1 exemplifies the characteristic changes seen in irradiation lesions of bone, as a result of the endarteritis obliterans produced by irradiation, and differs from the majority of reported cases of irradiation injury to the head and neck

of the femur in that the major changes occurred in the head of the femur and led to deformity of the head due to the influence of weight bearing as a traumatic factor. This in turn resulted in a rapidly progressive arthritis deformans of the hip, which was relieved by the performance of a vitallium® cup arthroplasty. Case 2 illustrates the more usual findings in a female patient following irradiation of the pelvis for carcinoma, with the development of a subcapital fracture of the neck of the femur over a period of months without a definite traumatic incident.

SUMMARY

A case of irradiation osteonecrosis of the head of the femur is presented, with a brief review of the literature. This is the third reported case of this lesion occurring in a male. A case of irradiation osteonecrosis of the neck of the femur occurring in a woman following irradiation of the pelvis for carcinoma is presented.

A short discussion of the clinical findings in such cases is given, the relatively long duration of symptoms prior to demonstrable physical signs and the relatively late occurrence of roentgenologic changes being emphasized. Pain alone as a symptom of metastasis is insufficient reason for ordering roentgen ray therapy. The pathologic findings, both gross and microscopic, demonstrate the basic factor in irradiation injury to be the production of endarteritis obliterans, with subsequent sterile necrosis of bone and cartilage. It is not primarily an inflammatory process. Secondary changes in the joint occur in the presence of added factors, particularly trauma. The total dose of irradiation in itself is not the only determining factor in the occurrence of necrosis of bone, but it is probably the most important one.

No evidence of metastasis has been found in the male patient by pathologic and clinical examination, and there is no clinical evidence of metastasis in the female patient.

PHYSIOLOGIC OBSERVATIONS ON A PATIENT WITH AN EXTERNAL PANCREATIC FISTULA

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THE FUNDAMENTAL information about external pancreatic secretion has been derived in the main from experimental studies on animals, although an occasional report is found in the medical literature about physiologic observations made on human subjects. Opportunity was afforded Wiper and one of us (J. M. M.) [1] to study three persons with external pancreatic fistula, and the results of these investigations have been published. A further chance was given to us to repeat and enlarge on the investigations made previously.

An external pancreatic fistula developed subsequent to a surgical procedure for a congenital duplication of the stomach in a 32 year old white man, the subject of this study. The duplication was removed by doing a partial gastrectomy. In the interpretation of the results which are concerned with the usually accepted theory of stimulation of pancreatic secretion, it should be remembered that a large part of the distal portion of the stomach, and so a considerable area of the acid-producing mucosa, was removed. For orientation, table 1 is a résumé of the various constituents of the blood of the patient before the observations detailed in following paragraphs were made.

It is appropriate to review the individual constituents of pancreatic juice and the values obtained by examination for some of them. The physical characteristics of human pancreatic secretion are well known. The juice is clear, opalescent and alkaline in reaction, with a p_H ranging as high as 8.5. In addition to various electrolytes, including a high concentration of bicarbonate, three chief enzymes are present. These are lipase, amylase and trypsinogen. The secretion of pancreatic juice is under both hormonal and nervous control. Secretin causes the production of water and electrolytes, while vagal stimulation results in

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1. Miller, J. M., and Wiper, T. B.: Physiologic Observations on Patients with External Pancreatic Fistula, Ann. Surg. **6**:852-872 (Dec.) 1944.

secretion which is thick, scanty and rich in enzymes. The two stimulants are normally effective simultaneously. The alkaline secretin juice washes the enzymes from the pancreatic alveoli.

The specific gravity of the pancreatic juice was 1.010, and the p_H was 8.47. Table 2 is a compilation of values for the various constituents of pancreatic secretion in pooled specimens obtained from the patient mentioned.

The total quantity of pancreatic juice secreted externally was the first problem to attract our attention. The usually accepted figure for the amount of pancreatic juice secreted in a normal human being in one day is about 700 cc. In twenty-seven investigations of external pancreatic fistula reviewed by McCaughan, Sinner and Sullivan,[2] the least amount of pancreatic juice secreted from an external fistula was 30 to 40 cc. per

TABLE 1.—*Values for Various Constituents of Blood Before Physiologic Observations Were Made*

Hemoglobin	11.6 Gm. per 100 cc.
Erythrocytes	4,380,000 per cu. mm.
Leukocytes	8,750 per cu mm.
Hematocrit value	43 per 100 cc.
Sedimentation rate	28 mm. per hour
Calcium	9.2 mg. per 100 cc.
Chloride as sodium chloride	450 mg. per 100 cc.
Bicarbonate as carbon-dioxide-combining power	64.5 volumes per cent
Sugar	98 mg. per 100 cc.
Cholesterol	227 mg. per 100 cc.
Amylase	234 Somogyi units
Serum protein	7.46 Gm. per 100 cc.
Serum albumin	4.44 Gm. per 100 cc.
Serum globulin	3.02 Gm. per 100 cc.
Nonprotein nitrogen	60 mg. per 100 cc.
Uric acid	4.55 mg. per 100 cc.

day and the largest 1,384 cc. In a previous communication by Wiper and one of us (J. M. M.),[1] 1 of the patients reported on secreted 1,770 cc. in one day. The patient on whom the present studies were made secreted as much as 1,342 cc. through the external fistula in one day. It should be noted that an attempt to influence the volume secreted was not made during this phase of the investigation. The patient ate a standard hospital diet and drank fluids dictated by his own volition. Digestion was not grossly altered, for apparently enough pancreatic secretion to care for the normal digestive needs was being delivered to the duodenum so that the fistula was not total in nature. It would seem reasonable that revision of the usually accepted amount of pancreatic secretion normally produced is in order, for the total quantity is much larger than 700 cc. in one day. In this particular patient the amount of

2. McCaughan, J. M.; Sinner, B. L., and Sullivan, C. J.: The External Secretory Function of the Human Pancreas: Physiologic Observations, Arch. Int. Med. **61**:739-754 (May) 1938.

pancreatic juice necessary for normal digestion and that secreted through the external fistula must have totaled more than 2,000 cc.

Pancreatic secretion was continuous throughout the day. A postprandial rise in rate of secretion was definitely present.

A review of table 2 will recall the large amounts of sodium, calcium, chloride and bicarbonate ions which are lost externally through the fistula. A significant amount of calcium, which is probably protein bound, is excreted. The assumption that the calcium is probably protein bound is supported by the observation that calcium and trypsinogen may be demonstrated in the same sample of pancreatic fluid which is not producing digestion. The addition of ionic calcium will cause activation of the trypsinogen and start digestion. Analysis of the pancreatic fluid collected from the external fistula revealed a calcium content of 2.9 mg. per hundred cubic centimeters on one occasion and 3.1 mg. on

TABLE 2.—*Values of Various Constituents of a Pooled Specimen of Pancreatic Juice*

Sodium	149.0 milliequivalents per liter
Potassium	4.3 milliequivalents per liter
Calcium	1.6 milliequivalents per liter
Chloride	95.0 milliequivalents per liter
Bicarbonate	61.0 milliequivalents per liter
Total protein	1.82 Gm. per 100 cc.
Albumin	1.22 Gm. per 100 cc.
Globulin	0.6 Gm. per 100 cc.
Nonprotein nitrogen	39 mg. per 100 cc.
Urea nitrogen	20.2 mg. per 100 cc.
Uric acid	1.22 mg. per 100 cc.

another. The serum calcium level on the first occasion was 9.2 mg. Forty-five per cent of serum calcium is protein bound, and in this particular instance the amount was calculated to be 4.1 mg. per hundred cubic centimeters. The value for calcium in the pancreatic juice in this patient, 2.9 mg., somewhat approaches the calculated value of protein-bound serum calcium.

The value for bicarbonate in the pancreatic secretion, 61 milliequivalents per liter, also attracts considerable interest. It will be recalled that the value for bicarbonate in the blood plasma is 27 milliequivalents per liter. It is apparent that a larger amount of bicarbonate is present in the pancreatic juice than in blood plasma. The reason for this fact is debatable. Komarov, Langstroth and McRae [3] wrote that the increased concentration of bicarbonate in rapidly secreted pancreatic juice is the result of increased respiratory metabolism in the gland.

3. Komarov, S. A.; Langstroth, G. O., and McRae, D. R.: Secretion of Crystalloids and Protein Material by Pancreas in Response to Secretin Administration, Canad. J. Research **17**:113-123 (May) 1939.

Hart and Thomas [4] stated that this theory is not consistent with the constant composition of the juice at higher rates of secretion unless the higher rates are obtained without a corresponding increase in the respiratory metabolism. They concluded that at moderate rates of secretion the concentrations of chloride and bicarbonate in dog's pancreatic juice are functions of the rate of secretion and independent of the stimulus used to provoke the secretion at higher rates and are constant and characteristic of the individual animal. These authors were able to confirm the observation of previous investigators that the concentrations for chloride and bicarbonate in pancreatic juice bear a reciprocal relationship to each other. The sum of their concentrations in milliequivalents per liter was approximately constant and isosmotic with the blood in the dog. Examination of a pooled specimen of pancreatic juice from the patient revealed a chloride level of 95 milliequivalents and a bicarbonate content of 61 milliequivalents. The sum is 156 milliequivalents. Gamble [5] wrote that the value for the blood plasma is 155 milliequivalents. This is a rather close check.

After the condition of the patient was stabilized during the postoperative period, a series of experimental studies were made. From the results obtained, it is felt that the use of some of these drugs is indicated and that of others contraindicated in the treatment of pancreatic fistula.

The specimens of pancreatic fluid were collected through a no. 10 French rubber catheter inserted into the fistulous tract. A small motor-driven suction apparatus was attached to the catheter to provide a negative pressure. For purposes of clarity, the results have been divided into categories.

1. DRUGS WHICH PRODUCED AN INCREASE IN FLOW OF PANCREATIC SECRETION

A. Pilocarpine.—A base line of 2.8, 2.3, 2, 3.2 and 3.3 cc. of fifteen minute periods was established, after which 0.005 Gm. of pilocarpine was administered intramuscularly. The readings for the remainder of the experiments were 3.6, 2.8, 5.9, 5.6 and 5.1 cc. for the same periods.

Goodman and Gilman [6] wrote that pilocarpine has a highly selective action on cells innervated by postganglionic cholinergic fibers. It was to

4. Hart, W. M., and Thomas, J. E.: Bicarbonate and Chloride of Pancreatic Juice Secreted in Response to Various Stimuli, Gastroenterology **4**:409-420 (May) 1945.

5. Gamble, J. L.: Physiology and Pathology of Extracellular Fluid, in Chemical Anatomy, Cambridge, Mass., Harvard Medical School, 1942.

6. Goodman, L., and Gilman, A.: The Pharmacological Basis of Therapeutics, New York, The Macmillan Company, 1941.

be expected that pilocarpine would stimulate the pancreatic secretion as it did.

B. Physostigmine.—A base line of 8.9 and 9.0 cc. for fifteen minute periods was established, after which 0.001 Gm. of physostigmine was administered intramuscularly. The readings for successive periods were 10.2, 9.8, 14.4, 11.6, 10.5 and 9.6 cc.

According to Goodman and Gilman,[6] physostigmine exerts its pharmacologic activity by inhibiting cholinesterase, which is responsible for the rapid and continuous destruction of acetylcholine. Physostigmine permits acetylcholine to exert its muscarinic effects on the smooth muscles, glands and heart and its nicotinic effects on skeletal muscles and autonomic ganglions. The effects of physostigmine are not always predictable, as the muscarinic action may be antagonized or even superseded by the nicotinic action of acetylcholine. In a previous set of experiments, pancreatic secretion was markedly decreased by physostigmine. If the muscarinic action predominates, one may expect an increased secretion of pancreatic juices. Conversely, if the nicotinic action predominates, a decrease in pancreatic flow might be expected. It is interesting to recall that physostigmine increases the epinephrine content of blood. The epinephrine causes vasoconstriction and decrease in pancreatic secretion. In the experiment mentioned, apparently the muscarinic effect predominated and an increase in secretion was obtained.

C. Hydrochloric Acid.—In the normal human being, it is well recognized that acid gastric chyme introduced into the duodenum will stimulate the flow of pancreatic secretion through activation of the secretin mechanism. Of a 10 per cent solution of hydrochloric acid 0.6 cc. was mixed with 225 cc. of water and the resultant solution given by mouth. The flow of pancreatic juice, which had been 2.8, 2.9 and 3.2 cc. for fifteen minute periods, changed to 5.1, 14.6, 12.1 and 5.1 cc. successively before returning to 3.2 and 2.9 cc.

D. Histamine.—Histamine would be expected to produce similar results as hydrochloric acid. A base line of 4.3 cc. of pancreatic secretion for a fifteen minute period was established, after which 0.1 cc. of a 1:1,000 solution of histamine phosphate was given subcutaneously. Readings for the following consecutive periods of fifteen minutes were 4.1, 3.9, 14.4, 12.3, 10.4 and 12.2 cc. The rise in secretory rate is due to the established action of histamine in increasing gastric acid secretion and motility, with consequent stimulation of the secretin mechanism.

E. Caffeine with Sodium Benzoate.—A base line of 6.1, 4.9 and 5.2 cc. in fifteen minute periods had been established when 0.5 Gm. of caffeine with sodium benzoate was administered subcutaneously. Consecutive readings for the next periods were 5.3, 7.2, 9.6, 8.5 and 6.8 cc.

The increase in pancreatic secretory rate was explained on a basis of increased flow of blood through the pancreas, which was the resultant of augmented cardiac output and peripheral vasodilatation.

2. DRUGS WHICH CAUSED A DECREASE IN FLOW OF PANCREATIC SECRETION

A. Epinephrine.—The subcutaneous administration of 0.4 cc. of a 1:1,000 solution of epinephrine produced a marked diminution of flow. Readings for the control periods were 7.3, 6.1 and 7.8 cc. for fifteen minute periods. The amounts secreted after the administration of the drug were 5.1, 4.8, 2, 3.1, 8.8 and 5.1 cc. Diminution of secretion was caused by decreased volume flow of blood in the pancreas due to the vasoconstrictor action of the drug.

B. Ephedrine.—It was expected that ephedrine would produce a result similar to that produced by epinephrine. A base line of 4.9 and 5.0 cc. in fifteen minute periods had been established when 0.045 Gm. of ephedrine was administered subcutaneously. The amounts secreted in successive fifteen minute periods were 3.9, 2.4, 3, 3, 3.6 and 4.2 cc. The decrease in pancreatic flow was the result of a lowered minute volume flow of blood through the pancreas due to the vasoconstrictor action of the drug.

C. Papaverine.—A base line of 8.7, 8.8 and 7.8 cc. of pancreatic secretion for fifteen minute periods had been established when 0.06 Gm. of papaverine was administered intramuscularly. The subsequent readings were 6.6, 4.5, 8.3 and 8.8 cc. A decrease in pancreatic secretion occurred and was due to the peripheral vasodilatation caused by the papaverine, with resulting decreased volume flow of blood through the pancreas.

D. Amyl Nitrite.—Amyl nitrite produces peripheral vasodilatation. A decrease in pancreatic secretion should be expected when the drug is given. A base line of 7.2, 8.2 and 7.8 cc. of pancreatic secretion in fifteen minute periods had been established when an ampul of amyl nitrite was broken and inhaled by the patient. Readings for the subsequent periods were 4.3, 5.2, 6.4, 5.8 and 4.8 cc. The expected result was obtained.

E. Atropine.—The action of atropine on the pancreas is not well understood. In a previous experiment by Wiper and one of us (J. M. M.),[1] a rapid and definite decrease of pancreatic secretion was found. It seemed worthwhile to investigate the action of atropine in the present subject, notwithstanding the fact that a large portion of the stomach had been removed. A base line of 4.5, 4 and 4.9 cc. for fifteen minute periods had been established when 0.0004 Gm. of atropine was given intramuscularly. The amounts of secretion for the subsequent

periods were 9.5, 4.9, 3.4, 3.6, 4.5 and 3.9 cc. Except for the initial rise to 9.5 cc., nothing significant occurred. The reason for the stimulation in the early part of the experiment is not clear.

Atropine produces a reduction of motility and acid secretion in the normal stomach, with resultant diminution in activation of the secretin mechanism. The action of atropine on the pancreatic secretion when a large portion of the stomach has been removed is open to speculation. With a patent gastrojejunostomy opening, the reduction of gastric motility which ordinarily results does not enter the problem. Since only a small portion of the acid-producing mucosa remained in the stomach, the degree of inhibition of acid production by atropine would be expected to be small. As a resultant of these two effects, a decrease in pancreatic secretion in this patient after the administration of atropine would not be expected. Atropine may have a direct effect on inhibition of pancreatic secretion by paralysis of the vagus nerve supplying the gland, although this effect is generally considered to be slight in nature.

F. Morphine Sulfate.—Pancreatic secretion is diminished in amount by administration of morphine sulfate in the human being when the stomach is intact. This observation was reported by Wiper and one of us (J. M. M.) [1] in a previous communication. The action is an indirect one through retardation of secretion of hydrochloric acid by the stomach, a decrease in gastric motility and a contraction of the pyloric sphincter. Since the actions of morphine are those which would tend to decrease the amount of stimulation of the secretin mechanism, it is reasonable to predict that a change in pancreatic secretion in this patient, with only a small amount of stomach remaining and a patent gastrojejunostomy opening, would not be seen. This proved to be the case and adds further proof of the method of action of morphine. A base line of 3.9 and 4.8 cc. for fifteen minute periods was established, after which 0.015 Gm. of morphine sulfate was administered intramuscularly. The amounts secreted in subsequent periods were 4.7, 5.6, 5.8, 5.1, 4.2 and 4.2 cc.

G. Meperidine Hydrochloride (Demerol Hydrochloride®).—Meperidine hydrochloride has actions similar to those of morphine. The drug should cause a decrease in the amount of pancreatic secretion. A base line of 7.8, 7.1, 6 and 6.6 cc. in fifteen minute periods had been established when 0.1 Gm. of the drug was administered intramuscularly. The amounts secreted in subsequent periods were 4.2, 2.2, 1.1 and 1.3 cc. The expected effect of the drug was observed.

H. Tetraethylammonium Chloride.—Little is known about the effect of tetraethylammonium chloride on pancreatic secretion. After a base line of 6.4 and 7.3 cc. of pancreatic secretion for fifteen minute periods had been established, 3 cc. of the drug (etamon® chloride, Parke, Davis &

Company) was given intramuscularly. Subsequent readings were 4.5, 4.3, 6.1 and 7.2 cc. This observation can be explained by the paralysis of the parasympathetic and sympathetic ganglions produced by the drug. Paralysis of the sympathetic vessels produces a peripheral vasodilatation with decreased blood flow through the pancreas and thus a smaller amount of secretion.

3. SUBSTANCES WHICH PRODUCE A VARIATION IN FLOW OF PANCREATIC SECRETION BUT WHICH ARE NOT PREDICTABLE

A. Furfuryl Trimethylammonium Iodide (Furmethide®).—Furfuryl trimethylammonium iodide has an action similar to that of methacholine chloride (acetyl-beta-methylcholine chloride). A base line of 9.4, 8.5, 8.9 and 8.2 cc. for fifteen minute periods was established, after which 0.6 cc. of furmethide® was administered intramuscularly. Subsequent readings were 9.5, 8.3, 9.6, 5.9, 11.5 and 10.9 cc. Goodman and Gilman [6] wrote that little effect on gastrointestinal secretions in man is noted even when acetyl-beta-methylcholine chloride in doses approaching the limit of tolerance is injected intravenously. A mixed effect of muscarinic and nicotinic stimulation was obtained in this patient. The result is not predictable and will vary from patient to patient. The result observed here bears out the conclusion of Goodman and Gilman.

B. Phenobarbital Sodium (Luminal Sodium®).—A base line of 5.6, 6.9 and 6.3 cc. for fifteen minute periods was established, after which 0.12 Gm. of luminal sodium® was administered intramuscularly. The subsequent readings were 6.1, 4.8, 4.2, 5.2 and 4.8 cc. A moderate decrease in pancreatic secretion resulted. The cause for the effect may be found in the decreased gastric secretion and diminished stimulation of the secretin mechanism. Previous investigators, Coffey, Koppanyi and Linegar,[7] found that barbiturates given in large hypnotic and anesthetic doses produced a reduction in gastric and pancreatic secretion.

C. Isotonic Sodium Chloride Solution.—Wiper and one of us (J. M. M.) [1] have reported previously that the administration of isotonic sodium chloride solution intravenously has stimulated the flow of pancreatic secretion. A base line of 7.3 and 7.6 cc. of pancreatic secretion for fifteen minute periods was established, after which 1,000 cc. of isotonic sodium chloride solution was administered intravenously in one hour and thirty minutes. The subsequent readings were 9.3, 7.3, 6.2, 6.1, 8.4, 7.2, 7.0 and 5.9 cc. Apparently, the dynamics of the circulatory system were not sufficiently altered in the patient to increase the secretory rate.

7. Coffey, R. J.; Koppanyi, T., and Linegar, C. R.: The Effect of Barbiturates on Digestive Secretion, Am. J. Digest. Dis. **7**:21-23 (Jan.) 1940.

D. Five Per Cent Dextrose in Isotonic Sodium Chloride Solution.—A base line of 6.2 and 5.7 cc. of pancreatic secretion for fifteen minute periods was established. In similar manner, 1,000 cc. of 5 per cent dextrose in isotonic sodium chloride solution was administered in one hour and twenty-three minutes. Subsequent readings were 8.2, 5.6, 2.3, 2.4, 4.6, 4.8, 5.7, 5 and 3.6 cc. Again, apparently, the hemodynamics were not sufficiently altered to produce an increase in secretion. In a pervious experiment by Wiper and one of us (J. M. M.) an increased flow of pancreatic secretion was produced by this solution given intravenously.

4. ALTERATIONS OF VOLUME FLOW INDUCED BY VARIOUS SUBSTANCES GIVEN BY MOUTH

A. Water.—A base line of 3.6, 2.8 and 2.1 cc. of pancreatic secretion for fifteen minute periods was established, after which 225 cc. of warm water was given by mouth. The subsequent readings were 4.2, 2.8, 2.9 and 3 cc. With a patent stoma, a change in p_H in the duodenum did not occur as the water apparently passed directly into the efferent loop of jejunum.

B. Food.—A base line of 7.4, 6.9, and 7.1 cc. was established, after which the patient was given a large meal of mixed composition. The patient ate this meal in twenty-eight minutes. The subsequent readings starting at the beginning of the meal were 8.4, 9.5, 10.1, 7.7 and 7.3 cc. The flow of pancreatic secretion was stimulated, as was expected.

5. ALTERATIONS OF VOLUME FLOW INDUCED BY VARIOUS SUBSTANCES ADMINISTERED THROUGH A LEVIN TUBE INTO THE JEJUNUM AT THE SITE OF THE GASTROENTEROSTOMY

A. Sodium Bicarbonate.—A base line of 3.9 and 4.2 cc. of pancreatic secretion for fifteen minute periods was established, after which 4 Gm. of sodium bicarbonate was inserted through a Levin rubber tube into the jejunum at the site of the gastroenterostomy. The subsequent readings were 3.5, 3.2, 4.4 and 4.1 cc. A decreased amount of pancreatic secretion, which might have been expected, was not found.

B. Magnesium Sulfate.—A base line of 3.2, 2.9, and 3.6 cc. of pancreatic secretion for fifteen minute periods was established, after which 50 cc. of a saturated solution of magnesium sulfate was given through a Levin rubber tube. Subsequent readings were 3.8, 5.1, 3.2 and 4.8 cc. A slight increase in the rate of secretion was found.

C. Olive Oil.—A base line of 4.2 and 4.4 cc. of pancreatic secretion for fifteen minute periods was established, after which 50 cc. of olive oil was given through a Levin rubber tube. The subsequent readings were

9.7, 6.8, 4.3 and 4.6 cc. These findings are similar to those reported by McCaughan, Sinner and Sullivan [2] and by Comfort, Osterberg and Priestley.[8]

D. Dextrose.—A base line of 3.8, 4.5 and 4.9 cc. of pancreatic secretion for fifteen minute periods was established, after which 50 cc. of 50 per cent dextrose was administered. The subsequent readings were 4.5, 4.7, 5.1 and 4.7 cc. A significant change in the amount of secretion was not found.

6. MISCELLANEOUS OBSERVATIONS

Smoking.—The patient used a moderate amount of tobacco. A base line of 3 cc. of pancreatic secretion was established. The patient smoked two cigarets in nineteen minutes. The subsequent readings, starting at

TABLE 3.—*Effect of Various Substances on Pancreatic Secretion*

Substances Producing an Increase in Flow	
a. Pilocarpine	f. Water
b. Physostigmine	g. Food
c. Hydrochloric acid	h. Magnesium sulfate
d. Histamine	i. Olive oil
e. Caffeine with sodium benzoate	
Substances Producing a Decrease in Flow	
a. Epinephrine	e. Atropine
b. Ephedrine	f. Morphine sulfate
c. Papaverine	g. Meperidine hydrochloride
d. Amyl nitrite	h. Tetraethylammonium chloride
Substances Producing Variations in Flow but Which Are Not Predictable	
a. Furfuryl trimethylammonium iodide	d. Two per cent dextrose in isotonic sodium chloride solution
b. Phenobarbital sodium	
c. Isotonic sodium chloride solution	
Substances Introduced by Levin Tube Which Did Not Produce a Change	
a. Sodium bicarbonate	b. Dextrose

the beginning of the smoking, were 2.9, 2.4, 3.4 and 2.8 cc. A significant effect on pancreatic secretion was not observed. In a previous experiment on a patient who did not smoke, conducted by Wiper and one of us (J. M. M.), a decrease in secretion occurred after two cigarets were smoked.

Indigo Carmine.—Five cubic centimeters of an 0.8 per cent solution of indigo carmine was given intravenously. The dye was not observed in the pancreatic secretion during the next twenty-four hours.

The actions of many of these substances can be predicted, while that of others cannot. A résumé of the results obtained from the use of the various substances is given in table 3.

8. Comfort, M. W., and Priestley, J. T.: External Pancreatic Fistula: Report of a Case with Physiologic Observations and Surgical Considerations, Proc. Staff Meet. Mayo Clin. **18**:409-416 (Nov. 3) 1943.

SUMMARY

The physiologic observations made in a patient with a pancreatic fistula, previously recorded by Wiper and one of us (J. M. M.) [1] and in the patient described here, have definite clinical applications. Certain definite aids to therapy are suggested.

1. Marked alterations in the amount of hemoglobin, number of erythrocytes, plasma electrolytes, plasma protein and fluid balance may occur. The loss of sodium calcium, chloride and bicarbonate ions and water may be large. Correction of the anemia and the restoration of the blood volume and plasma protein deficiency may be accomplished by the transfusion of adequate amounts of citrated whole blood and the use of irradiated blood plasma. The administration of isotonic sodium chloride, along with the corrective measures for the protein deficiency, will alleviate the symptoms peculiar to the syndrome associated with an external pancreatic fistula. It should be recalled that the excessive or too rapid administration of intravenous fluids of any type may stimulate the pancreas to greater secretion. The calcium lost through the fistula should be replaced with the intravenous fluids. The lost pancreatic fluid shold be collected, flavored as with grape juice and given to the patient to drink. The fluid is the ideal medium for replacing lost electrolytes.

2. Of the several drugs which reduce pancreatic secretion, ephedrine is the most efficacious. It may be given in the therapeutic doses for prolonged periods.

3. An effective method of protection of the skin when trypsinogen becomes active must be provided. The mechanical device described by Wiper and one of us (J. M. M.)[9] in combination with the local application of aluminum paint or the apparatus used on the patient reported on with dilute acetic acid have been found efficacious.

4. The majority of fistulas will close spontaneously when the metabolism of the patient is restored to normal. If the fistula persists, purely local measures to effect closure are worthless. The surgical procedure of choice and the time to perform it must be dictated by individual circumstances. An anastomosis of the fistula with the stomach, duodenum or jejunum should be done whenever possible. If such a procedure cannot be accomplished, division and ligation of the fistula at the pancreas should be carried out.

9. Wiper, T. B., and Miller, J. M.: Surgical Aspects of Pancreatic Fistula, Ann. Surg. **120**:52-59 (July) 1944.

CARCINOMA OF THE AMPULLA OF VATER OF MINUTE SIZE

An Unsuspected Cause of Obstructive Jaundice

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SOUND medical practice dictates the necessity for surgical exploration in patients who present a clinical and laboratory pattern consistent with obstructive jaundice. When at operation routine search including careful palpation fails to disclose the suspected obstructive lesion, the operator, knowing well the difficulties inherent in the differential diagnosis of jaundice, may begin to doubt the validity of his preoperative impression. If, after duodenotomy and direct inspection of the ampullary region, no lesion can be seen, a diagnosis of either primary hepatitis or the passage of a common duct stone may be made. It is apparently not well appreciated that a major degree of biliary obstruction may be produced by carcinomas of the ampulla of Vater of such small size as to be undetectable at the time of operation on palpation or even direct inspection after duodenotomy.

The stimulus to present the following material arose as a result of a discussion which followed the presentation of case 1 at a Boston University clinicopathologic conference. A number of clinicians of wide experience who were present expressed unfamiliarity with this concept and stressed the desirability of publishing it. A review of our material discloses 13 cases of carcinoma of the ampulla of Vater among 18,000 autopsies performed at the Mallory Institute of Pathology of Boston City Hospital between the years 1926 and 1946. Five of these cases are presented as examples of small symptom-producing lesions. In 2 of the 5 patients no gross lesion was seen at autopsy; 1 of these had come to operation and the lesion had escaped detection at that time. In 2 other cases a very small tumor was present at autopsy which had not been detected at operation. The fifth patient, on whom no opera-

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tion had been performed, revealed a small tumor at autopsy. In 2 additional cases a small tumor of the ampullary region was an incidental finding at autopsy.

REPORT OF CASES

CASE 1.—A 66 year old white man was first seen on the Fifth Medical Service of Boston City Hospital, at which time he complained of a yellow tint of the skin and eyes of six weeks' duration. Just prior to his admission there had developed marked generalized pruritus and severe weakness. There has been no anorexia, nausea, vomiting or change in the color of the stool. No pain was present, but the patient had recently noted a dragging sensation in the epigastrium. During the course of this illness there had been a loss of weight of 25 pounds (11.3 Kg.) The past history was noncontributory. Physical examination showed a deeply jaundiced man not appearing acutely ill. The right eye was scarified and the left conjunctiva yellow. The heart was slightly enlarged to the left. The blood pressure was 100 systolic and 70 diastolic. The liver was palpable approximately 2 fingerbreadths beneath the right costal margin, and a soft rounded mass, moving with respiration, was palpable beneath its right lobe. Slight tenderness was present over the epigastrium. The remainder of the examination was essentially noncontributory. Laboratory examination showed that the urine contained bile; the red blood cell count was 3,450,000, and the white blood cell count ranged between 7,000 and 10,000. The differential smear showed 69 polymorphonuclear cells, 30 lymphocytes and 1 eosinophil. The bleeding time and the clotting time were 3 and 5 minutes respectively. The icteric index was 40. Urobilinogen was present in the urine in a dilution of 1:10. The stools were clay colored, and one of the three examined gave a guaiac-positive reaction. Roentgenologic studies of the upper intestinal tract showed nothing pathologic other than a diverticulum of the third portion of the duodenum. The patient was placed on a high carbohydrate diet, fats were restricted and mild sedation was prescribed. He was transferred to the surgical service but refused operation.

Second Admission.—The patient was readmitted to the Fifth Medical Service approximately fourteen and a half months later complaining of pain in the chest of two weeks' duration. He was too ill to give a detailed history. Two weeks before his admission he had first noted a severe, constricting, substernal pain, which had since persisted in the form of intermittent attacks. The pain did not radiate and was not related to exertion or to respiratory motion. There had been some attendant dyspnea and cough. Physical examination showed a poorly nourished white man with marked icterus of the skin and the left conjunctiva. Examination of the chest revealed dulness at both apexes and increased fremitus over the upper lobe of the right lung. The trachea was displaced slightly to the right. There were a few crepitant rales at the right base. No cardiac abnormality was noted. The blood pressure was 120 systolic and 90 diastolic. There was pronounced voluntary spasm over the upper region of the abdomen. As this regressed the liver was found to be palpable 6 fingerbreadths beneath the right costal margin and a large, irregular mass was palpated on its surface. Laboratory examination revealed that the red blood cell count was 4,000,000. The white blood cell count and the differential count were unchanged. The nonprotein nitrogen was 67 mg. per hundred cubic centimeters. The icteric index was 50. Urobilinogen was present in the urine in a dilution of 1:10. The electrocardiogram was interpreted as showing right bundle branch block. A roentgenogram of the chest showed consolidation of the upper half of the right lung. Gastrointestinal roentgenograms were normal. Evidence of mild congestive failure developed, which responded well to digitalization. There was

gradual improvement in his general condition until the twelfth day in the hospital, when, without any complaints, he suddenly died.

Pathologic Findings.—The skin, sclera and buccal mucosa were moderately icteric, and the legs showed pitting edema. The peritoneal cavity contained approximately 300 cc. of clear yellow watery fluid, and each pleural cavity contained 1,000 cc. of similar fluid. The pericardium was distended with 100 cc. of slightly sanguineous, fibrinous fluid, and a layer of fibrin covered a portion of the epicardium on the anterior surface of the left ventricle. The myocardium at the apex was thinned to 0.5 cm. and was replaced by gray fibrous tissue; the muscle underlying the epicardial fibrinous deposit was soft and yellow, with a hemorrhagic border. The coronary arteries showed atherosclerosis, but no occlusion could be demonstrated. The lower lobes of the lungs were atelectatic and congested. The liver weighed 2,000 Gm. and was pale and mottled green. The gallbladder was not remarkable. The common duct was dilated throughout its length to a diameter of 4 cm. Careful examination of the bile ducts and the ampulla of Vater failed to demonstrate a cause for the apparent obstruction. The remainder of the examination revealed nothing of importance.

In microscopic sections from the ampulla of Vater the normal mucosal pattern was replaced by irregular glandular spaces lined by well differentiated columnar cells. These acini extended downward into the submucosa. A few were filled with amorphous basophilic material.

Anatomic Diagnosis.—The anatomic diagnosis was adenocarcinoma of the ampulla of Vater with obstruction of the bile ducts, bile stasis of the liver, icterus and acute and healed myocardial infarcts with fibrinous pericarditis and cardiac failure.

Comment.—This patient had a clinical picture of obstructive jaundice of at least sixteen months' duration. At autopsy no obstructing lesion was demonstrated although obstruction was evidenced by a greatly dilated common bile duct. Microscopic sections of the ampulla of Vater revealed an adenocarcinoma.

Demonstration of this tumor is attributable to the custom of the Mallory Institute of Pathology, promulgated by the late F. B. Mallory, of cutting numerous sections of the ampullary region in all cases in which dilatation of the common duct is observed without apparent cause for the obstruction.[1]

CASE 2.—A 47 year old white woman was admitted to the medical service with the chief complaint of jaundice. She had been well until seven months before her admission, at which time she became weak. Soon thereafter she noticed that her skin had become yellow and she began to experience nausea. There were frequent gaseous eructations and occasional vomiting thirty to sixty minutes after meals. These symptoms lasted five or six weeks, and then the patient regained her usual good health. Three months prior to her admission she again noted a yellow tint of the skin, became weak and had frequent bouts of vomiting. Her urine became dark and the stools pale gray. For the next two months these symptoms persisted and were accompanied with a constant aching discomfort in the right posterior region of the chest. Twenty-four hours before admission she had a severe sharp pain in the back which radiated around the left side to the loin and the abdomen. The pain was considerably alleviated by the passage of a large, foul-smelling stool. The past history was noncontributory. Physical examination revealed a well nourished woman with notable icterus. The mucous membranes were pale. There was slight dulness and a few fine rales over both apexes. Diaphragmatic excursion was limited. The heart showed a gallop rhythm; there were an aortic diastolic

1. Mallory, K.: Personal communication to the authors.

murmur and an apical systolic murmur. A smooth mass was palpated in the right upper quadrant of the abdomen. Laboratory examination revealed a hemoglobin content of 23 per cent. The blood smear was characteristic of secondary anemia. Stools were examined repeatedly for blood, and approximately one-half the total number gave a guaiac-positive reaction. The surgical consultant palpated a mass in the right upper quadrant which was nontender and slightly movable. A diagnosis was made of probable carcinoma or possible chronic infection of the gallbladder, and she was transferred to the surgical service for operation.

Operation revealed an enlarged, thick-walled gallbladder which emptied on pressure. The liver showed numerous small, white, raised nodules. The remainder of the abdominal exploration revealed no pathologic changes. The gallbladder was removed. After operation she failed steadily. Jaundice remained constant, and bile drained from the operative wound. Death occurred on the seventh postoperative day.

Pathologic Findings.—The skin, scleras and buccal mucosa were deeply icteric. A 10 cm., healing, rectus-splitting scar in the right upper quadrant was present. The peritoneal cavity contained 200 cc. of bile-stained purulent fluid; all the surfaces were dull, gray and injected, and loops of bowel and omentum were matted together by fibrinous adhesions. A 1.5 cm. layer of fibrinous exudate covered the diaphragmatic surface of the liver. The gallbladder was absent. The folds of the duodenal mucosa were prominent in the region of the ampulla of Vater, but no palpable induration was present and no tumor was seen on dissection of the ampulla. The bile ducts were moderately dilated. The remainder of the viscera were not remarkable except for congestion of the lung bases, scattered 0.1 to 0.3 cm. hard, raised, yellow nodules on the surface of the liver and spleen and bile staining of all the organs.

In microscopic sections from the region of the ampulla of Vater large irregular glandular spaces lined by atypical columnar epithelium arranged in several layers replaced the mucosa and extended down into the submucosa. Tumor giant cells and mitotic figures were abundant. The yellow nodules in the liver and spleen were healed granulomatous lesions. The remaining histologic sections served only to confirm the gross diagnosis.

The surgical specimen was interpreted grossly and microscopically as chronic cholecystitis. One small healed granulomatous focus was observed in the wall of the gallbladder.

Anatomic Diagnosis.—The anatomic diagnosis was adenocarcinoma of the ampulla of Vater, acute generalized peritonitis, healed miliary tubercles and a postcholecystectomy state.

Comment.—This patient had obstructive jaundice for approximately seven months. At operation the gallbladder was removed and no cause for the obstruction of the biliary tract was demonstrated. Although at autopsy the mucosal folds in the region of the ampulla of Vater were prominent, careful dissection of the ducts and the ampulla disclosed no gross tumor. Histologic examination, however, revealed a carcinoma of the ampullary region.

Case 3.—A 62 year old white man was admitted to the hospital with the chief complaints of dull epigastric pain and jaundice which had been present for nine months. The pain had been relieved by the intake of food and hot fluids. The stools had been pale. Pruritus had been constant. One month after the onset of these symptoms the patient underwent a cholecystotomy, with removal of "169 gallstones." Two months later he underwent a cholecystoenterostomy, although it was stated that no biliary obstruction could be demonstrated. After this operation the jaundice disappeared, the stools became normal in color and the patient felt much improved.

Four months prior to his admission the patient began to feel weak and listless. Pain returned and the urine became dark, the stools light and the skin icteric. Steady loss of weight was noted. On admission he showed icterus of the skin and the conjunctivas, an enlarged, nontender liver and a large round mass in the right upper quadrant which was believed to be an incisional hernia. Laboratory examination revealed a hemoglobin content of 50 per cent and a white blood cell count of 9,000. The urine contained bile. The icteric index was 75. The stools were pale; tests for occult blood were not carried out. A surgical consultant diagnosed a probable carcinoma of the pancreas or a possible stone in the common duct. Operation revealed a nonfunctioning anastomosis between the gallbladder and the jejunum. Biopsies of these organs were later reported to show biliary cirrhosis and chronic pancreatitis. The common duct could not be exposed. No stones were palpable, nor any mass in the ampullary region. After operation the patient did not rally, and he died twenty-four hours later with signs of bronchopneumonia.

Pathologic Findings.—Externally, the body was icteric. Healing and healed scars in the right upper quadrant were present. The peritoneal cavity contained 500 cc. of watery brown fluid, and the bowel was covered by a fibrinopurulent exudate. There was evidence of leakage around the line of suture of the recent cholecystojejunostomy. An 0.8 by 0.4 cm. ovoid, firm, yellow tumor mass was located at the ampulla of Vater and completely obstructed the common bile duct. The liver was dark green and weighed 2,800 Gm. The bile ducts were markedly dilated. The remainder of the examination revealed no pertinent findings.

Microscopically the tumor was a well differentiated adenocarcinoma. A typical picture of biliary cirrhosis was found in sections from the liver. The pancreas showed diffuse fibrosis, with considerable lymphocytic infiltration.

Anatomic Diagnosis.—The anatomic diagnosis was adenocarcinoma of the ampulla of Vater with obstructive jaundice, biliary cirrhosis and chronic pancreatitis with fibrosis; acute generalized peritonitis, and a postcholecystojejunostomy state.

Comment.—In this patient symptoms of obstructive jaundice developed nine months before death and were unrelieved by a cholecystotomy, with removal of numerous stones. Only temporary relief was afforded by cholecystoenterostomy. Recurrent jaundice led to a third operation, at which no cause for obstruction was demonstrated. At autopsy an 0.8 by 0.4 cm. tumor completely obstructed the terminal end of the common bile duct. This lesion had been undetected by palpation at the time of operation.

Case 4.—A 55 year old white woman was admitted to the hospital because of jaundice of two and one-half months' duration. The jaundice had been persistent and painless. Pruritus had been present throughout the illness. The patient believed that she had lost about 25 pounds (11.3 Kg.) of weight during the year preceding her admission. The color of the stools and urine had not been noted. She had suffered an attack of typhoid thirty-six years before the onset of her present illness. About three years before she suffered two attacks of pain in the right upper quadrant, which her physician had diagnosed as "gallbladder attacks." Physical examination revealed no masses or palpable organs. Laboratory examination showed a hemoglobin content of 75 per cent and a red blood cell count of 3,830,000. The nonprotein nitrogen was 25 mg. per hundred cubic centimeters, the icteric index was 100 plus and the bilirubin was 4,9 mg. Of the five stools examined, one showed occult blood. The patient was transferred to the surgical service and came to operation about two weeks after her admission. The gallbladder was found to be moderately distended and covered with adhesions. The common bile duct was dilated to about 2.5 cm. in diameter. The gallbladder was

opened, and attempts to pass a probe into the common duct met with failure. The common duct was opened and a probe passed into the duodenum. The operator noted that there was "some thickening of the head of the pancreas." The liver was said to be normal. An operative diagnosis of carcinoma of the head of the pancreas was made, and the common duct was drained by means of a T tube. After the operation large amounts of bile drained. Stools were consistently light gray. The icteric index continued to rise, and the patient steadily failed. She died one month after operation.

Pathologic Findings.—The body was that of an intensely icteric woman. A sinus tract which drained bile led from the superior end of a partially healed incision in the right upper quadrant to the common bile duct. The bile ducts were dilated to twice their normal size, and the common duct contained dark bile and fine black gravel. A 1 by 0.8 by 0.4 cm. firm gray tumor surrounded the ampulla of Vater and invaded the wall of the common bile duct. The gallbladder was contracted; the wall was 0.2 cm. thick and was opaque; the lumen contained black gravel and gray mucoid fluid. The cystic duct was obstructed by a 1 cm. stone impacted in the neck of the gallbladder. The liver, which weighed 1,700 Gm., was mottled, with a green tinge.

Microscopically the ampullary tumor was composed of columnar epithelium growing in papillary fashion. The tumor was infiltrated by many lymphocytes. The pancreas showed a marked increase in fibrous tissue which was infiltrated by lymphocytes, and the liver showed an increase in the connective tissue of the portal areas, with an increase in the number of small bile ducts and stasis of bile.

Anatomic Diagnosis.—The diagnosis was papillary adenocarcinoma of the ampulla of Vater with biliary cirrhosis and pancreatic fibrosis; chronic cholecystitis; (stones in cystic duct), and a sinus tract from the common bile duct to the abdominal skin.

Comment.—This patient came to operation about three months after the development of what appeared to be typical obstructive jaundice. At operation there was evidence of obstruction in the cystic duct, but a probe could be passed from the common duct into the duodenum. No ampullary lesion could be palpated. Because of thickening of the head of the pancreas, a diagnosis of carcinoma was made. Drainage of the common duct was carried out, but the patient did not respond and died one month after operation. At autopsy a 1 by 0.8 by 0.4 cm. firm gray tumor surrounded the ampulla of Vater and a 1 cm. stone was impacted in the neck of the gallbladder.

Case 5.—An 83 year old white woman was admitted to the Fifth Medical Service on Dec. 10, 1945, with the chief complaint of a dull, aching, nonradiating pain in the right upper quadrant of one month's duration. Soon after the onset of this pain she became weak and noted that her urine was dark. Three days before her admission the stools became light. No jaundice was noted. Physical examination revealed a markedly icteric, poorly nourished elderly woman who appeared chronically ill. The heart was enlarged to the left, and soft, poorly transmitted apical and aortic systolic murmurs were audible. The blood pressure was 165 systolic and 85 diastolic. A hard mass, believed to be liver, was palpated in the right upper quadrant beneath the costal margin. Several observers also palpated a smaller soft mass which moved with inspiration. Laboratory examination revealed a red blood cell count of 3,100,000, a hemoglobin content of 10 Gm. and a white blood cell count of 7,300, with a moderate increase in the polymorphonuclear cells. Specimens of urine gave a positive reaction for bile. The stool was brown and formed with a positive benzidine but a negative guaiac reaction. The icteric index

was 75. The total protein was 4.72 Gm. The prothrombin time was 100 per cent of normal. The reaction to the cephalin flocculation test was 3+.

The patient was given fluids parenterally consisting of dextrose and vitamins. There was no improvement, and jaundice became more pronounced. Consolidation of the right side of the chest was demonstrable clinically and in roentgenograms taken with a portable machine. Seven days after her admission severe pain developed over the right lower region of the chest, and she became cyanotic and died within a few minutes.

Pathologic Findings.—The skin, scleras and buccal mucosa were intensely jaundiced. The peritoneal cavity contained approximately 200 cc. of bile-stained fluid. The ampulla was replaced by a hard gray tumor measuring 0.4 cm. in length and 0.4 cm. in diameter which had narrowed the lumen to a pinpoint orifice. The common bile duct measured 3 cm. in diameter and contained dark bile. The lesser ramifications of the biliary tree were also dilated. The gallbladder was distended by 150 cc. of dark viscid bile and contained several 0.5 cm. dark stones. The liver was enlarged, smooth and greenish yellow. The only other gross findings were several small pulmonary emboli, a fibrotic scar in the myocardium and uniformly contracted granular kidneys.

Microscopically the ampullary tumor was a scirrhous adenocarcinoma. There was an increase in the connective tissue of the portal areas of the liver, and the dilated bile ducts were filled with and surrounded by an acute inflammatory exudate. The kidneys were histologically typical of benign nephrosclerosis.

Anatomic Diagnosis.—The diagnosis was adenocarcinoma of the ampulla of Vater with biliary cirrhosis, cholangitis and pericholangitis and obstructive jaundice; multiple pulmonary emboli; healed myocardial infarction; chronic cholecystitis and cholelithiasis, and benign nephrosclerosis.

Comment.—The patient had symptoms suggestive of early disease of the biliary tract for one month and on admission to the hospital showed a clinical picture of obstructive jaundice. She failed rapidly on supportive therapy, and at necropsy a tumor measuring 0.4 by 0.4 cm. was found at the ampulla of Vater.

Two other patients with carcinoma showed no gross obstructive lesions at autopsy and had no symptoms suggestive of obstruction of the bile ducts. In 1 a slight prominence of the papilla of Vater aroused suspicion, and in the other dilatation of the common bile duct led to histologic study of the papilla. In both cases a microscopic diagnosis of carcinoma of the papilla of Vater was made.

PATHOLOGIC PROCESS

The site of origin of tumors of the ampullary region cannot usually be determined with exactness. A tumor may arise from the papilla of Vater, from the adjacent duodenal mucosa, from the termination of the common bile duct or from the termination of the duct of Wirsung. Unless the process is seen early, the intimate anatomic relationship of these structures soon results in involvement of all, with similar clinical and pathologic sequelae.

Grossly the benign tumors of this region usually take the form of a small polypoid growth which does not infiltrate the deeper structures and which is composed of well differentiated cells arranged in an acinar or villous pattern.

Carcinoma of the ampullary region grows either as a papillary fungating mass which tends to ulcerate or as a diffuse infiltrating scirrhous tumor which narrows the ducts. Only about 20 per cent of the carcinomas progress far enough to produce secondary extensions and metastasis to the regional lymph nodes and the liver (Ewing). Histologically an adenocarcinoma is most frequently observed. The architecture may be that of an infiltrating tumor composed of acini lined by columnar or cuboidal cells with varying amounts of intervening fibrous stroma or of fine villous and papillary processes lined by similar cells.

The pathologic changes in the liver and pancreas are usually secondary to obstruction. Dilatation of the bile ducts proximal to the point of obstruction and distention of the gallbladder are frequently seen. Cholangitis, pericholangitis and bile stasis with or without biliary cirrhosis may be observed. The duct of Wirsung is also dilated in many instances, and occasionally pancreatitis is found.

It is unusual for a carcinoma of the ampulla of Vater to reach a large size. Lieber, Stewart and Lund [2] stated that these tumors vary from small, barely perceptible localized thickenings or plaques to large cancerous masses. Vaught [3] estimated that the size varies from a few millimeters to more than 3 cm. Cooper [4] distinguished variations in size according to the manner of growth and indicated that the papillary lesions may be from a few millimeters to 3 cm. in size, with most less than 1 cm., while the ulcerating lesions are from 1 to 3 cm., with none less than 1 cm. The cases which he presents, however, do not conform to this observation, since most of the tumors were 3 or more centimeters in diameter and only one was less than 2 cm. in size. Baggenstoss [5] found that in 25 cases of polyp of the ampulla of Vater found incidentally the size varied from 2 to 5 mm. In only 2 instances were the bile ducts dilated, and in 2 others the gallbladder was distended. Twenty-eight cases of carcinoma were reviewed, and in most of these the tumors were "very small," varying in size from 1 to 3 cm. Although the tendency to compare the size of these neoplasms to well known objects confuses any evaluation of case and series reports, the experience of most authors regarding the size of ampullary tumors conforms with the reports just cited.

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2. Lieber, M. M.; Stewart, H. L., and Lund, H.: Carcinoma of the Periampullary Portion of the Duodenum, Ann. Surg. **109**:219-393, 1939.

3. Vaught, A. M.: Primary Carcinoma of the Ampulla of Vater, Am. J. Surg. **52**:473-489, 1941.

4. Cooper, W. A.: Carcinoma of the Ampulla of Vater, Ann. Surg. **106**:1009-1034, 1937.

5. Baggenstoss, A. H.: Major Duodenal Papilla, Arch. Path. **26**:853-866 (Oct.) 1938.

CLINICAL PICTURE

The clinical picture of tumors of the ampullary region has been discussed in such detail elsewhere as to require only brief comment here. Lieber, Stewart and Lund [2] have reviewed 205 cases taken from the literature and included 17 cases of their own in a complete discussion of the subject. More recently Sharpe and Comfort [6] presented a concise clinical description of the disease based on 40 cases studied at the Mayo Clinic. Inasmuch as symptoms and signs are due largely to obstruction of free flow of bile into the intestinal tract, it is understandable why this tumor so closely simulates carcinoma of the head of the pancreas. The latter has in the past been considered the neoplasm most common in association with obstructive jaundice, but recently Cattell [7] disclosed that at the Lahey Clinic lesions of the ampullary region were more common. Jaundice has been by far the most prominent sign, having been present in all but 4 of the 222 cases discussed by Lieber, Stewart and Lund and in all the 40 cases studied by Sharpe and Comfort. It must be emphasized, however, that jaundice is not always constant and progressive. Frequently it waxes and wanes in intensity and may disappear entirely for short periods. As in carcinoma of the head of the pancreas, pain is now generally appreciated as being common and is present in more than one half of the cases. It is often intermittent and may be accentuated by ingestion of food. A truly colicky type of pain is frequently reported, but the coexistence of biliary stones in approximately 20 per cent of patients makes strict evaluation of this type difficult. The gallbladder is palpable in about 50 per cent of the cases. Although this finding is of no assistance in differentiating tumors of the head of the pancreas from carcinoma of the ampullary region, it is considered of significant value in ruling out the presence of cholelithiasis. The frequent association of palpable enlargement of the gallbladder with obstructive jaundice due to tumor and the lack of such enlargement in obstruction due to stone have been well documented in medical literature under the term "Courvoisier's law." However, the not infrequent coexistence of biliary stones and ampullary tumors must be kept in mind. Twenty-two of the patients reviewed by Sharpe and Comfort showed at some time in their course chills and fever; 10 of these had stones of the common duct. Nausea, vomiting, diarrhea and constipation, although frequently reported, have little specific diagnostic value. With obstruction of the flow of pancreatic secretion, development of a clinical picture suggestive of the sprue

6. Sharpe, W. S., and Comfort, M. W.: Carcinoma of the Papilla of Vater, Am. J. M. Sc. **202**:238-245, 1941.

7. Cattell, R. B.: Pancreatoduodenal Resection, New England J. Med. **232**:521-526, 1945.

syndrome may occur, as in the case described by Norris.[8] The presence of blood in the stool has received considerable emphasis as a diagnostic clue. Cooper [4] stressed the belief that this finding is frequent in carcinoma of the ampullary region and considered it to be of value in differentiating ampullary from pancreatic tumors. Of the 38 patients reported on by Sharpe and Comfort, 10 were noted to have tarry stools and 15 others showed occult blood.

Many observers have been tempted to explain the intermittency of pain and jaundice together with the presence of blood in the stool on the basis of recurring ulceration of a carcinoma of the papilla. Such a hypothesis is reasonable, but there is not sufficient correlation between the clinical features and the pathologic findings to permit one to be entirely satisfied with this explanation. The bleeding tendency common to all patients with obstructive jaundice is perhaps the variable factor.

In short, the clinical picture of carcinoma of the ampullary region of the duodenum resembles that in cases of carcinoma of the head of the pancreas and stones in the common duct. This fact is well exemplified by the review of Lieber and his group, who found that while the correct diagnosis was made in 39 cases, carcinoma of the pancreas was suspected in 25 and biliary calculi were believed to be the cause of the obstruction in 24. When one is confronted with a patient showing severe jaundice and a palpable gallbladder, as in a case of carcinoma of the pancreas, coupled with variation of intensity of the jaundice and attacks of colicky pain, as in a case of stone in the biliary tract, carcinoma of the ampullary region should be suspected. If, in addition, blood is found consistently in the stools and there is moderately severe secondary anemia, such a diagnosis should be more seriously considered.

In addition to those noted, other conditions may, although rarely, give rise to obstruction. Benign tumors would obviously closely simulate the clinical picture of carcinoma of the ampulla. In 1 patient seen at the Boston City Hospital a pedunculated papilloma, simulating the ball-valve stone syndrome, produced chills, fever and jaundice intermittently over a period of several years. D'Offry [9] has pointed out the simulation of cancerous obstruction by subacute or chronic pancreatitis.

COMMENT

The small size of neoplasms of the ampulla of Vater frequently makes detection difficult, even after symptoms have developed. Upcott [10]

8. Norris, E. H.; Beard, A. H., and Gerber, L. S.: Atrophy of the Pancreas with Extreme Fatty Metamorphosis of the Liver and Steatorrhea, Arch. Path. **26**:1234-1244 (Dec.) 1938.

9. D'Offry, T. M. J.: Some Recent Advances in Pancreatic and Biliary Tract Surgery, Brit. J. Surg. **34**:116-127, 1946.

10. Upcott, H.: Tumors of the Ampulla of Vater, Ann. Surg. **56**:710-725, 1912.

wrote in 1912: "There is probably no position within the body outside the central nervous system where a growth, while yet so small, is heralded by more widespread symptoms than at the lower end of the common bile duct." He went on to state that symptoms of obstructive jaundice can be caused by a growth no bigger than a pea. Cohen and Colp [11] mentioned that occasionally small plaquelike lesions are overlooked in a hurried operative examination. According to McCabe,[12] carcinoma of the ampullary region produces jaundice before it has reached a size large enough to make it definitely palpable through the duodenal wall. Cooper,[4] Foldes and Heyer [13] and River, McNealy and Ragins [14] have all emphasized that if no cause for obstructive jaundice can be demonstrated in the gallbladder, common duct or region of the head of the pancreas, the duodenum should be mobilized and opened, with direct inspection of the ampullary region. Even this procedure may not be sufficient to establish a diagnosis, for, according to Lieber, Stewart and Lund [2] symptomatic lesions may actually be undetectable on direct inspection. Cattell [7] stated that a positive diagnosis can be made by means of transduodenal exploration of the ampulla but that in most cases the projecting tumor can be palpated through the duodenal wall.

In the series reviewed by Lieber and his associates of 122 cases which came to operation a tumor was demonstrated in 86. In 59 of these it was palpated through the duodenal wall, and in 10 there was obstruction to the passage of a sound. In 16 of the cases the precise method of diagnosis was believed to have been established by direct inspection of the ampullary region. In 8 instances the tumor was discovered only by a second operation, and in 1 case it was not found even after three operations. In 25 cases the tumor was not discovered at operation even though it averaged from 2 to 3 cm. in size.

Not only are small tumors difficult to palpate through the duodenal wall, but also tumors of large size may escape detection by this method of diagnosis. Grove and Rasmussen [15] failed to palpate one the size of a walnut. Walters [16] was unable to detect a tumor 2 cm. in diameter

11. Cohen, I., and Colp, R.: Cancer of the Periampullary Region of the Duodenum, Surg., Gynec. & Obst. **45**:332, 1927.

12. McCabe, L. G.: Carcinoma of the Ampulla of Vater, Canad. M. A. J. **38**:438-442, 1938.

13. Foldes, J., and Heyer, F. W.: Early Carcinoma of the Ampulla of Vater, Am. J. Cancer **36**:574-577, 1939.

14. River, L.; McNealy, R. W., and Ragins, A. B.: Carcinoma of the Ampulla of Vater, Am. J. Surg. **52**:289-296, 1941.

15. Grove, L., and Rasmussen, E. A.: Benign Papilloma of the Ampulla of Vater, Am. J. Surg. **64**:141-143, 1944.

16. Walters, W.: Successful Resection of the Ampulla of Vater, Surg., Gynec. & Obst. **55**:648-651, 1932.

and cited a case of Pemberton's in which the tumor was overlooked although it was of similar size. Nor can obstruction to the passage of a sound be considered a reliable method of diagnosis. Baggenstoss [5] has asserted that in some cases a probe can be passed through the papilla of Vater even though there is clinical evidence of complete obstruction. In the case of Cohen and Colp,[11] which will be described, such a problem arose.

A review of the literature in order to find cases similar to those included in this report reveals a small number of cases of tumor of the ampullary region of 1 cm. or less in size which could be seen grossly, either at operation or at postmortem examination. Lieber and his associates [2] mentioned that some tumors were of the size of a pea. Outerbridge [16a] described one tumor the size of a "small cherry" and two the size of a pea. A "lentil-size" adenoma described by Christopher [17] was estimated by Baggenstoss [5] to be 5 mm. in diameter. Among the 28 cases of carcinoma of the ampulla of Vater reported by Baggenstoss, in 3 the tumor was "small, annular and constricting" and in 1 it measured 7 mm. in size. Cooper,[4] Hunt and Budd [18] and River and others [14] each described a tumor of similar size.

There is a striking paucity of reported cases of obstructive ampullary tumors which could not be detected by inspection. We have been able to find only 2 such cases, and because of the bearing of this paper on such lesions they will be cited in some detail.

The patient described by Foldes and Heyer [13] was a 56 year old white man in whom jaundice developed one week prior to his admission to the hospital. Five days before admission he had epigastric pain and gaseous eructations. The stools were light and the urine dark brown. The patient had been in good health except that he had lost about 10 pounds (4.5 Kg.) of weight over a period of six weeks. On his admission to the hospital he was jaundiced. The liver and spleen were not palpable. A circumscribed, tender mass, suspected of being the gallbladder, was palpated in the right upper quadrant beneath the costal margin. The gallbladder was not demonstrated in cholecystographic studies, and a series of gastrointestinal roentgenograms showed a normal condition. The urine contained bile, a faint trace of albumin and a few casts and white cells. The stools were light yellow and showed no occult blood. The hemoglobin content was 94 per cent. The red blood cell count was 4,620,000, and the white blood cell count was normal. The icteric index was reported as 12.4.

16a. Outerbridge, G. W.: Carcinoma of the Papilla of Vater, Ann. Surg. **57**:402-426, 1913.

17. Christopher, F.: Adenoma of the Ampulla of Vater, Surg., Gynec. & Obst. **56**:202-204, 1933.

18. Hunt, V. C., and Budd, J. W.: Transduodenal Resection of the Ampulla of Vater for Carcinoma of the Distal End of the Common Duct, Surg., Gynec. & Obst. **61**:651-661, 1935.

A laparotomy was performed eleven days after the patient's admission to the hospital. The abdomen contained a large amount of bile-stained fluid. The liver was enlarged and smooth, and the gallbladder was distended. The stomach and duodenum appeared normal. The head of the pancreas showed some thickening, but no new growth was found. There was no evidence of calculi in the biliary tract. "Since careful search failed to reveal a tumor, a surgical diagnosis was made of hydrops of the gallbladder due to cholecystitis, and cholecystectomy and duct drainage were performed." After operation there was drainage of bloody fluid from the operative site; increased distention in the upper region of the abdomen and jaundice continued unabated. Death occurred on the tenth day after operation.

At autopsy the papilla of Vater was enlarged and projected forward and downward into the lumen of the duodenum. It was firm and indurated, but the mucous membrane covering it appeared normal. A probe easily entered the lumen at the apex of the papilla but was arrested immediately beyond. The papilla was incised, revealing the wall to be firm and gray for an area 3 mm. in thickness. Histologic examination revealed gradual malignant transformation at the point in the ampulla 5 mm. from the apex of the papilla diagnosed as adenocarcinoma.

The patient described by Cohen and Colp [11] was a 47 year old woman admitted to the hospital with a history of progressively increasing jaundice for two months. The stools had been clay colored and the urine dark. There had been no abdominal pain. The patient had lost about 20 pounds (9.1 Kg.) of weight. Physical examination at the time of her admission revealed a markedly jaundiced, emaciated woman. The liver and gallbladder were distinctly palpable.

At operation the gallbladder and the common duct were found to be dilated. Cholecystostomy and choledochostomy were performed. A probe could be passed into the duodenum with difficulty. The pancreas was enlarged but not hard. (No mention was made of the duodenum.) The patient died of shock eight hours after operation.

At autopsy the papilla of Vater was said to appear prominent, in the shape of a nipple, and edematous. A probe was passed through its opening only by the use of force. There was a small mass of tissue (1 mm.) about the orifice of the papilla which felt hard and which was whitish on cut section. An enlarged hard node was adjacent to the cystic duct. Histologic examination revealed a carcinoma of the ampulla of Vater, "squamous and speroidal in type," and the lymph node was replaced by a squamous cell carcinoma.

One could maintain with considerable justification that the coexistence of signs of biliary obstruction and a small obstructive tumor could be expected in the early stages of growth of nearly every tumor. The

case reported by Foldes and Heyer [18] falls into such a category. In our patients, biliary obstruction was of sufficiently long duration to rule out the possibility that we were dealing solely with "young" neoplasms. It is of interest that the 2 patients with no gross lesion demonstrable at postmortem examination had suffered from biliary obstruction for seven and sixteen months respectively, while the patient with the largest neoplasm gave only a three months' history of obstructive symptoms. In none of our patients were symptoms present for less than one month prior to their admission to the hospital. Thus, we feel that there is no consistent correlation between the duration of symptoms and the size of the obstructive lesion. Another fact deserving of emphasis is that in the cases reported here no metastasis was found even though the tumors had been present for considerable lengths of time. With the possible exception of case 3, there is no evidence that the obstruction may have been primarily due to the presence of cholelithiasis, only to be followed at some later date by the development of a neoplasm.

Probable steps in determining the cause of obstructive jaundice include exploration of the common duct, passage of a probe into the duodenum, palpation of the duodenum and finally duodenotomy with direct visualization of the region of the ampulla of Vater. As exemplified by 2 of the cases described here and the 2 cited from the literature, diagnosis may still be impossible. Consequently the procedure suggested by Orr [19] of biopsy of the papillary area may be indicated. If such is deemed inadvisable or if the result proves negative, and there still remains reasonable suspicion of the presence of malignant obstruction, consideration should be given to the employment of such operative procedures as will establish free flow of bile into the intestinal tract. After these are carried out, further investigation or even an immediate more radical operation can be conducted. Emphasis has frequently been placed [20] on the necessity of ruling out the presence of innocuous obstructive lesions before carrying out the extensive surgical procedure called for in the treatment of ampullary neoplasms. We feel that similar emphasis should be placed on the importance of making certain that a small carcinoma is not present while there is still time for surgical correction.

At autopsy attention should be given to the procedure of cutting a block of tissue from the ampullary region and making numerous sections for detection of a malignant process. This is indicated particularly when gross inspection fails to disclose the anatomic cause of obstructive jaundice.

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19. Orr, T. G.: Pancreaticoduodenectomy for Carcinoma of the Ampulla and Ampullary Region, Surgery **18**:144-158, 1945.

20. Cattell.[7] D'Offry.[9]

SUMMARY

Evidence is presented that a major degree of biliary obstruction may be produced by a carcinoma of the ampulla of Vater so small as to be undetectable by palpation or even direct inspection at the time of exploratory operation. Recognition of this lesion even at postmortem examination may require numerous histologic sections of the ampullary area. This type of lesion is not too rare. The importance of an ampullary carcinoma as a cause of obstructive jaundice is stressed and the differential diagnosis, including the need for surgical exploration, discussed.

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RELIEF OF PAIN IN CHRONIC RELAPSING PANCREATITIS BY UNILATERAL SYMPATHECTOMY

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CHRONIC relapsing pancreatitis is characterized by recurring attacks of pain in the upper abdominal region, often radiating to the back or to either side of the hypochondrium. The pain is usually severe during the first few days of the attack and is followed by a dull, distressing ache during the subsequent five to seven days. Increase of blood amylase or lipase, transitory hyperglycemia and glycosuria, steatorrhea and creatorrhea and roentgenologic evidence of calcification in the pancreas help to establish the diagnosis. The attacks may recur so frequently and with such great severity that the patient is unable to work or, worse still, may become addicted to opiates. For the relief of pain in the intractable case, dorsal sympathectomy and splanchnicectomy have proved successful.[1]

The rationale of this procedure is based on the fact that after bilateral sympathetic denervation pain cannot be elicited by applying pressure

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1. (*a*) Rienhoff, W. F., and Baker, B. M.: Pancreolithiasis and Chronic Pancreatitis, J. A. M. A. **134**:20-21 (May 3) 1947. (*b*) Mallet-Guy, P.; Jeanjean, R., and Serrellaz, P.: Résultats éloignés de la splanchnicectomie unilatérale dans le traitement des pancréatites chroniques, Lyon chir. **40**:293-314, 1945. (*c*) DeTakats, G., and Walter, L. E.: The Treatment of Pancreatic Pain by Splanchnic Nerve Section, Surg., Gynec. & Obst. **85**:742-746, 1947. (*d*) Ray, B. S., and Console, A. D.: The Relief of Pain in Chronic (Calcareous) Pancreatitis by Sympathectomy, ibid **89**:1-8, 1949.

against the pancreas. White and Smithwick [2] described the sensory pathways of the pancreas from experimental and clinical data, but much of the evidence was inferential. Ray and Neill [3] studied the mechanism of pain throughout the entire intestinal tract, biliary tract and pancreas after unilateral and bilateral removal of the sympathetic chain from the seventh thoracic to the third lumbar ganglion and of the splanchnic nerves down to the celiac ganglion. These operations had been performed in hypertensive patients, 6 of whom underwent abdominal operations subsequently under local anesthesia. In 1 of the cases they showed that after removal of the left splanchnic nerves and the left sympathetic chain from the seventh dorsal to the third lumbar segment pain from pressure on the head of the pancreas was experienced in the right hypochondriac region. After a similar procedure was performed on the right side in another patient and the pancreatic stimulus repeated, pain was felt in the left hypochondriac region. No pain could be elicited after a bilateral sympathectomy. One of their patients with calcareous pancreatitis experienced her initial pain in the midepigastrium and the back. After a sympathectomy on the right side for hypertension, the pain in the midepigastrium disappeared but pain of a lesser degree existed in the left hypochondriac region. All pain disappeared after completion of the sympathectomy on the left side. The authors were convinced that the head of the pancreas has a bilateral innervation.

Absence of visceral pain has been observed in patients after extensive sympathectomy and splanchnicectomy for hypertension. In 1 of deTakat's [1c] patients painless jaundice developed although a stone was found occluding the common duct at operation. Weeks reported silent perforations of duodenal ulcers after sympathectomy, although it is difficult to understand how the abdominal findings consistent with peritonitis were absent since they depend on the transmission of afferent impulses along the somatic nerves. The absence of pain after excision of the lower dorsal sympathetic chain and splanchnic nerves has been striking in the cases of chronic relapsing pancreatitis reported. This operative procedure was employed in the following 3 patients with successful results.

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2. White, J. C., and Smithwick, R. H.: The Autonomic Nervous System, New York, The Macmillan Company, 1941. White, J. C.: Review of Sympathetic Nervous System, Surgery **23**:834, 1947.

3. Ray, B. S., and Neill, C. L.: Abdominal Visceral Sensation in Man, Ann. Surg. **126**:709-724, 1947.

REPORT OF CASES

CASE 1.—R. R., a 32 year old man, was admitted to the hospital for the fifth time on July 22, 1948, with a complaint of pain in the right costovertebral angle. Three years previously epigastric, postprandial distress, nausea and vomiting developed. Similar attacks occurred intermittently, but he received no medical attention. His first admission to this hospital was on Aug. 5, 1947, when a diagnosis of posterior penetrating duodenal ulcer with pancreatic lithiasis was made. He responded well to a Sippy regimen and the administration of antispasmodics and antacids. He returned to the hospital again in February 1948, because of persistent nausea and vomiting. At this time he complained of severe pain in the right costovertebral angle associated with epigastric distress, which subsided rapidly. He was advised to return to the hospital as soon as the severe pain started again and was readmitted on March 20, 1948, at the height of an attack. The pain disappeared soon after his admission, and he was discharged with the advice that he should eat small meals and avoid alcohol. His fourth admission was on July 6, 1948, during another relapse, but the pain subsided quickly. The patient was discharged and advised to return to the hospital for sympathectomy during the next attack. After his discharge he remained well until the morning of his fifth admission, when he again experienced severe pain in the right costovertebral angle radiating around to the right upper quadrant. The pain was intermittent, sharp and accompanied with anorexia, nausea and frequent retching and vomiting. The past history and family history were irrelevant.

Physical examination revealed a thin, well developed, white man appearing older than his stated age of 32. He was morose and anxious but intelligent and cooperative. There was tenderness in the right costovertebral angle as well as tenderness and spasm over the epigastrium.

Repeated blood amylase determinations ranged between 16 and 64 units (normal range, 0 to 300 [4]). On one occasion after his second admission a glucose tolerance test revealed a typical diabetic curve. Roentgenograms of the gallbladder were normal on two occasions. After each admission abdominal roentgenograms revealed pancreatic calcifications.

Clinical Course.—On July 27, 1948, splanchnic resection was performed on the right via a transpleural approach through the bed of the tenth rib. The fibers of the greater, lesser and lowest splanchnic nerves from their origin down to the diaphragm were removed. In addition, a thoracic sympathectomy was completed from the seventh to the twelfth ganglion inclusively. Convalescence was complicated by atelectasis followed by pneumonia in the lower lobe of the left lung, which cleared after the use of tracheal aspirations and penicillin. He had no recurrence of pain in the right costovertebral angle or epigastrium after operation. His appetite was good and his morale excellent. To test the effect of the splanchnicectomy and sympathectomy, overdistention of the renal pelves was performed on Aug. 16, 1948, in an attempt to produce pain. Pain was elicited in the left flank but not in the right. The patient was discharged on Aug. 17, 1948. A communication from him eight months later revealed that he had had no further attacks of pain or distress.

CASE 2.—P. A. C., a 35 year old man, was admitted to the hospital on Sept. 8, 1948, with the chief complaint of pain in the epigastrium radiating to the left hypochondrium. In March 1947 he first experienced pain in the upper abdominal area

4. Clark, D. G. C.: Personal communication, to be published.

followed by distention, nausea, vomiting and jaundice. He was treated at a hospital in California, where he was told that he had hepatitis. He returned to the hospital two weeks later because of another attack of severe midepigastric pain. A diagnosis of perforated peptic ulcer was made and operation performed. The positive findings at operation were acute pancreatitis and a diseased gallbladder containing stones. A cholecystectomy was done. The third attack occurred in September 1947 and was not accompanied with jaundice. He had no more definite attacks until thirty-six hours before his admission, when he experienced moderately severe midepigastric pain radiating to both upper quadrants of the abdomen. He was nauseated and vomited on four occasions.

The past history revealed that he used to consume large amounts of alcohol but had been a teetotaler during the past year. His appetite was generally poor, and he had lost about 20 pounds (9.1 Kg.) during the past year. He complained of epigastric distress with "lots of gas."

Physical examination revealed a well developed, fairly well nourished man who complained of pain in the upper abdominal area. The abnormal findings were a well healed, right rectus scar and moderate tenderness without spasm in the midepigastrium.

The urine gave a positive (2 plus) reaction for sugar consistently. The glucose tolerance curve was within normal limits. The fasting blood sugar level was 124 to 148 mg. per hundred cubic centimeters. The serum amylase was 8 units. Several examinations of the duodenal drainage showed no ova or parasites. The white blood cells ranged between 11,000 and 14,600.

Roentgenologic examination of the entire intestinal tract revealed no abnormalities. No calcification was observed in the region of the pancreas.

Clinical Course.—During the first five days in the hospital the pain abated. On Sept. 24, 1948, the patient experienced a recurrence of the pain, with radiation to the left upper quadrant, which was relieved after an injection of 3.5 cc. of tetraethyl ammonium chloride. On the following day he experienced an exacerbation of the pain, which subsided in twelve hours. A complete splanchnicectomy on the left side together with excision of the sympathetic chain from the sixth to the twelfth dorsal ganglion was performed. Postoperatively, tension pneumothorax developed on the left side, which was relieved by catheter drainage for twenty-four hours. On the third postoperative day atelectasis of the middle lobe of the right lung was found, which cleared after several endotracheal aspirations. A chest tap on the sixth postoperative day revealed 450 cc. of hemorrhagic fluid. The remainder of the postoperative course was uneventful, and he was dicharged on the fourteenth day after operation. He was asymptomatic when seen in the follow-up clinic seven months after operation.

Case 3.—A. S. C., a 29 year old white male veteran of World War II, was admitted to the hospital on Nov. 10, 1948, with the chief complaint of bouts of pain in the upper abdominal area during the past ten years. The pain was dull at first, with occasional knifelike twinges, and confined to the midepigastrium and the right upper quadrant. The attacks lasted two to three weeks and occurred every eight to ten months. The pain was usually associated with anorexia but not with vomiting. There was no history of hematemesis, melena or jaundice. In 1938, after a series of roentgenograms of the gastrointestinal tract, he was told that he had "stomach ulcers." Since his discharge from the army, the attacks had increased in severity and frequency. He was admitted to a neighboring hospital

on Oct. 2, 1948, where roentgen studies revealed a normal-functioning gallbladder and a slight irregularity of the pylorus and the duodenal cap. The second portion of the duodenum was narrowed and deformed. The patient underwent a posterior gastroenterostomy on October 11. According to the operative note, "a mass about one-half the size of an orange" was palpated behind the second portion of the duodenum. Aspiration yielded only a few flecks of blood. A lymph node in close proximity to the mass was removed, and pathologic examination revealed it to be normal. His convalescence was uneventful, and he was discharged on Nov. 2, 1948. Postoperatively, pain recurred with greater severity. During the two months prior to his admission to this hospital he had lost 25 pounds (11.3 Kg.).

The past history revealed that he had had infrequent exposure to lead, paint and kerosene during the past six months. He had been divorced in January 1945 and had "upset nerves" since that time.

Physical examination revealed a well developed, poorly nourished white man. The abdomen showed a well healed incision in the right upper paramedian area. Tenderness without spasm was elicited in the midepigastrium and the right upper quadrant. No masses were noted.

Laboratory examination of the urine showed it to be normal. The white blood cell count was 9,300, with a normal differential count. Gastric analysis revealed no free hydrochloric acid even after the use of histamine. The cephalin flocculation test elicited a negative reaction. Thymol turbidity was 2.5 units; alkaline phosphatase, 9.65 units; the direct van den Bergh reaction 1.0 mg., and the indirect reaction 3.0 mg. The glucose tolerance test revealed a normal curve. The blood amylase content was 8 and 10 units on two occasions.

A series of roentgenograms of the gastrointestinal tract showed enlargement of the head of the pancreas in the region of the duodenal knee, with a possible defect in the posterior wall of the body of the stomach, probably secondary to enlargement of the head and body of the pancreas. Roentgenograms of the gallbladder were indeterminate.

The patient continued to complain of intermittent, severe pain in the epigastrium and the right upper quadrant. During one of these attacks, block of the right splanchnic nerve afforded him immediate and complete relief of symptoms. On Dec. 8, 1948, transthoracic sympathectomy and splanchnicectomy on the right side were performed.

The sympathetic chain, together with all three splanchnic nerves was removed from the sixth to the twelfth dorsal ganglion. Mild atelectasis of the lower lobe of the left lung followed the operation but responded quickly to bronchoscopic and endotracheal catheter aspirations. His convalescence after the second postoperative day was uneventful, and he was discharged on the tenth postoperative day. A letter received from him three months after operation revealed that he had had no pain and was extremely happy with the postoperative result.

COMMENT

The surgical treatment of chronic relapsing pancreatitis with intractable pain has varied. Removal of pancreatic calculi,[5] total pancreatec-

5. Lionello, J.; Ficarra, B. J., and Ryan, N. H.: Pancreatic Calculi: Report of Seven Cases in Two of Which Cure Was Effected by Pancreaticolithotomy, Arch. Surg. **48**:137-143 (Feb.) 1944. King, A. B., and Waghelstein, J. M.: Calcification of Pancreas, Arch. Int. Med. **69**:165-176 (Feb.) 1942.

tomy [6] and cholecystectomy and choledochostomy [7] have been performed with varying success. The last operation should be employed when there is definite evidence of disease of the gallbladder. Attempts to remove pancreatic calculi are fraught with danger and technically unsatisfactory because of the diffuse involvement of the pancreas. Total pancreatectomy carries an appreciable mortality and morbidity and, usually, should be applicable only to malignant pancreatic disease.

Since most patients with chronic relapsing pancreatitis live many years with their disease, the operation of dorsal sympathectomy and splanchnicectomy by removing the sensation of pain, can make their existence much more comfortable. This procedure has been performed with uniformly good results by several investigators.[1] Most of the operations have been unilateral, employed on the side where the pain has been most striking. This approach is in keeping with the experience derived from the treatment in the 3 cases described. Ray and Console [1d] have employed bilateral sympathectomy in the treatment of 5 patients with chronic calcareous pancreatitis, with gratifying results. They advocated a bilateral resection of the sympathetic chain from the eleventh thoracic to the first lumbar ganglion and of the distal 8 cm. of the greater splanchnic nerves. Since all 3 patients in this series have been asymptomatic there has been no indication for a contralateral operation up to the present time.

The advisability of performing vagal resections simultaneously is open to question. Rienhoff [1a] employed the combined operation in 1 patient, with a successful outcome. The rationale of the vagotomy can be attributed to the reduction in the amount and character of the pancreatic secretions. This phenomenon has been observed in the experimental animal by Lium.[8]

In an effort to decrease the frequency of attacks of pancreatitis, the patient should be instructed to eat small meals and abstain from all alcoholic beverages. Administration of sorbitan mono-oleate (tween 80®) and pancreatin tablets is probably worthwhile because of the appreciable incidence of steatorrhea and fatty degeneration of the liver. Kerin and Katzenstein [9] found associated disease of the liver in all their 14 cases of chronic relapsing pancreatitis. All the measures described had been employed preoperatively in this series but failed to influence the frequency or severity of the attacks favorably.

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6. Whipple, A. O.: Radical Surgery for Certain Cases of Pancreatic Fibrosis Associated with Calcareous Deposits, Ann. Surg. **124**:991-1008, 1946.

7. Gambill, E. E.; Comfort, M. W., and Baggenstoss, A. H.: Chronic Relapsing Pancreatitis: An Analysis of Twenty-Seven Cases Associated with Disease of the Biliary Tract, Gastroenterology **11**:1-33, 1948.

8. Lium, R.: Etiology of Acute Pancreatitis: An Experimental Study, Surgery **24**:593-604, 1948.

9. Kerin, R. J., and Katzenstein, R.: Liver Disease in Chronic Relapsing Pancreatitis: A Report of 14 Cases, Meriden Hosp. Bull., 13-23, April, 1949.

SUMMARY

The rationale for dorsal sympathectomy and splanchnicectomy in the treatment of chronic relapsing pancreatitis is presented. The performance of this operation in 3 patients with successful results is reported.

ADDENDUM

Since this paper was submitted for publication, the authors have performed three additional unilateral splanchnic-dorsal sympathectomies for severe, chronic, relapsing pancreatitis, with gratifying results.

TREATMENT OF FRACTURES WITH LONG-STANDING OSTEOMYELITIS

Results of Use of the Tibial Sliding Graft

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MUCH OF the literature to date dealing with the treatment of war fractures has described a high incidence of success with a low incidence of infection. However, most of the cases reported occurred early in the war. I was impressed by the high incidence of infection in patients treated in several army general hospitals in 1947 and 1948. This report includes observations on the treatment of fractures with long-standing osteomyelitis and specifically the results in 25 consecutive cases.

The patients included in this report were seen after the war was over and were treated in 1947 and the early part of 1948. Most of them sustained their fractures during the war and because of infection did not receive definitive treatment until later. In 25 consecutive cases of tibial fracture there was an average of 30.8 months from the occurrence of the injury to the time of the graft and in these same cases an average of 15.8 months of continuous active infection following injury. The longest time from the injury to the final graft was forty months. There were 8 cases in which the interval was thirty-six months; the longest active infection was of a duration of twenty-nine months, and there were 5 cases with twenty-four months of active infection.

These figures would seem to show that the cases in this report were those which were not included in the end results given in previous articles or possibly were reported as failures. The treatment in these cases is as important as the treatment in cases in which an early cure is obtained, and I believe that it poses special problems.

Routine cultures of the depths of operative wounds at the time of surgical intervention in all cases by several surgeons doing bone grafts during 1947 revealed that positive pyogen cultures were obtained in 50 per cent of them regardless of how long the patients had been clinically free of infection.

The bulk of this work was done at Percy Jones General Hospital, Colonel Carl W. Rylander, Chief of Surgical Service.

The results in 85 consecutive patients with grafts coming to operation during the summer months of 1947 in one army general hospital revealed a postoperative incidence of infection in 43 per cent. This does not mean that the graft failed in 43 per cent, because union and eventual cessation of drainage occurred in some of them.

It must be remembered that earlier reports gave the results in cases in which grafting was performed. Great care was taken in the selection of cases and in the time for operation. The patients referred to here must be considered problem patients. The earlier cases reported frequently involved men in generally better condition, who had not been in hospitals as long, had not suffered retrogressive changes in their tissues, had had infection for a shorter time and frequently were not injured as badly. The "bottom of the barrel" cases in which the final operation was performed an average of thirty months after injury had the following problems: 1. There was more soft tissue change, with more scarring and impairment in circulation. 2. There were more severe injuries to start with. 3. The infections were most resistant and virile. 4. They involved patients in a condition which could be classed only as poor constitutionally. For example, nutritional studies frequently revealed anemia in which the total circulating hemoglobin and protein contents were reduced though concentration per cubic centimeter was nearly normal. (So far, this fact has only been shown to be true; a program to study this is under way in both army and civilian installations.) 5. A small percentage of the patients were uncooperative, and their proper treatment was interfered with by their actions. 6. Drainage was encountered for as long as twenty-eight months. 7. There were prolonged immobilization and disuse as a result of waiting for infection to clear or for soft tissues to be repaired, which led to decreased circulation, marked diminution in circumference of the extremity, fibrosis and almost irreparable changes in joints.

Definite factors relative to the actual grafting were observed which frequently meant the difference between success and amputation. The speed of actual operation plus the lack of trauma to tissues was considered important. It was found that massive grafts, which are certainly the choice in recent fractures, often so overloaded the tissues that infection, delayed union or nonunion usually resulted. It is thought better to restore continuity of the extremity, even though it be precarious in these cases, and to do later second stage reenforcing grafts. It was noted frequently that after an early precarious result the second stage operation was not needed when the function of the extremity was returned. It was surprising to note the amount of regeneration that took place with relatively small grafts.

An attempt was made whenever possible to restore early activity of the part, whether with a walking cast or with a brace. This was

important for psychic as well as physiologic reasons. It prevented further retrogressive changes. The men were frequently discouraged because of their long stay in the hospital and occasionally lost the will to get well. This seemed to interfere with healing, and it certainly delayed ambulation and increased the incidence of pain on ambulation. It was particularly important in cases in which amputation was carried out on the other side. The longer an amputee went before he walked, the harder it was for him to make the adjustment. It became increasingly necessary to have at one's command procedures which could offer quick, sure healing and a low incidence of infection.

Ideally, a method was needed which was easy and quick, combining rigid fixation with the potentialities of cancellous bone, and one which utilized a minimum of metallic fixation, since metal certainly predisposes toward infection in old cases of osteomyelitis.

For tibial fractures, the sliding graft seemed to me to meet these qualifications. Results in 25 cases will be recorded later. The sliding graft lent the necessary rigidity but was usually osteoporotic enough so that it seemed to be more easily revascularized and incorporated than cortical bone.

It was usually possible to complete the entire operation in less than an hour with minimal trauma to the tissue, the principles of Dallas B. Phemister being adhered to in that the tissue was not disturbed at the fracture site more than was necessary for the application of the graft. By using cabinetmakers' principles in cases with complete nonunion and by wedging the graft in the donor area and usually inlaying or preferably driving the graft into the medullary cavity of the other end of the fracture, rigid fixation could be obtained and the wound in the shrunken leg easily closed without tension. In cases with fibrous or partial bony union an attempt was made to place the graft on the lateral surface of the tibia as an onlay without fixation, again without disturbing the fracture site other than to get opposition of the graft and the recipient area.

Although I cannot prove it, it has been my impression and that of others that there seemed to be an immunity of local tissue which had developed in these cases and would result in the toleration of a sliding graft and not another type.

The method of casting was important in that with careless casts position could easily be lost. It was found that by flexing the knee to about 45 degrees in a long leg cast for the first month no change of position occurred in any of the 25 consecutive cases reported. No untoward effects of this knee flexion were noted either.

The only criterion in these cases prior to surgical intervention was that the skin be in good condition and that the fracture site be dry for six months prior to surgical intervention. In 2 cases pus was dis-

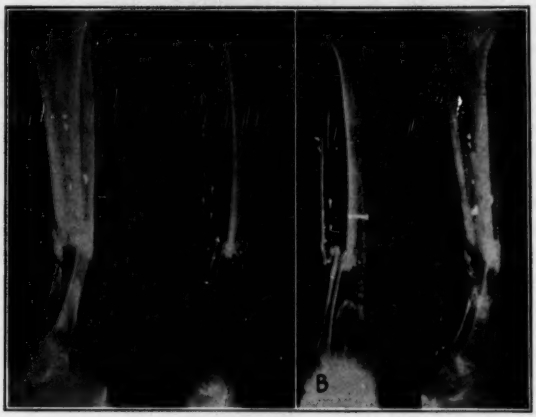

Fig. 1.—*A*, status of fracture six months before graft. Extremely small amount of soft tissue with small circumference of leg due to wasting. Twenty-seven months between injury and graft, with twelve months of active infection. Full thickness skin graft to the site prior to graft. *B*, seven months after the graft at the time of discharge. Patient was wearing short brace with full cuff and not using crutches.

Fig. 2.—*A*, five months before graft. Nineteen months between injury and graft, with thirteen months of active infection. Large tube pedicle inlaid at fracture site. *B*, nine months after graft. There was slight drainage after graft for three months. Patient was discharged in short leg brace.

Fig. 3.—*A*, just prior to graft, thirty-two months after injury. Patient had arteriovenous aneurysm from injury, which was repaired. Extensive skin work was done prior to graft after sixteen months of active infection. *B*, four months after graft. Patient discharged in long leg brace walking without crutches.

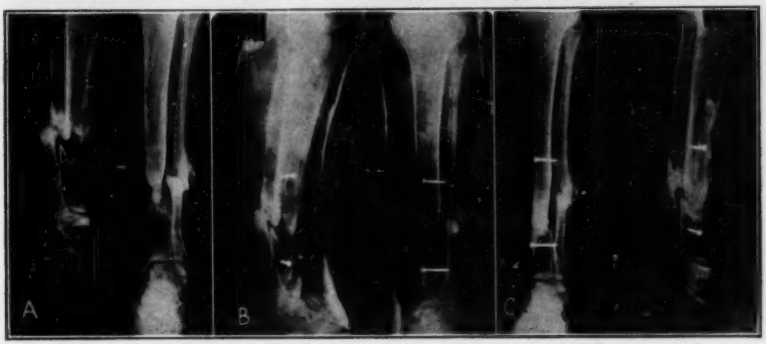

Fig. 4.—*A*, two months before graft, thirty-six months between injury and graft, with nine months of infection. Extensive abdominal tube pedicle was transferred to the leg, with severe dermatitis following, which lasted for eighteen months before graft could be done. *B*, immediately after operation. *C*, six and a half months after graft. Patient walked in short leg brace at the end of four months and was discharged at the end of six months wearing brace only part of time.

covered at the fracture site at operation. Granulation tissue was removed and everything prepared for the graft as far as the fracture site was concerned, and the wounds were closed. Both promptly healed and both were successfully grafted in one month. The six months' waiting period was selected on the basis of results in 85 cases of old war wounds grafted in early 1947. Thirty-three patients were operated on after the fracture site had been dry for six months, with postoperative infection in 39.33 per cent; 52 were operated on after the fracture site had been dry for three months, with postoperative infection in 48 per cent. An analysis of the 85 cases showed that it did not make much difference how much time elapsed after six months but that within that time the incidence of infection steadily increased.

Fig. 5.—*A*, at time of injury. *B*, just prior to graft, twenty-four months after injury, with ten months of active infection. Large pedicle flap inlaid. Pus at fracture site at first graft attempt after clinical absence of infection for over six months. This was cleaned out and the wound sutured closed. Wound healed promptly, and the graft was done one month later, with no postoperative infection. *C*, six months after graft was used to fuse subtibial and subtalar joints which were previously ankylosed with early traumatic arthritis. Patient was in short leg walking cast at this time for one month and was discharged one month later in short leg brace.

These results are only in patients with long-standing osteomyelitis. However, it is the author's opinion that the rule of operation six months after infection disappears should be adhered to if the initial infection was at all severe or if the injury was extensive.

In general, the following conclusions can be drawn for the treatment of old war fractures or other severe fractures in which there has been long drainage:

1. The most important factor is not to overload the extremity with bone and metal which could not be tolerated by the size of the extremity and the status of its circulation and tissue. Union and function should first be restored with external support. In the few cases in which regeneration does not occur regrafting should be done when the tissues are ready.

2. Six months should be allowed to elapse after the last drainage, and the skin should be satisfactory.

3. Wedging and intramedullary position and muscular pressure should be relied on to hold grafts at fracture sites to prevent the constant threat of infection around metal.

4. The value of massive grafts with secure metal fixation is proved, but they will not work in these cases.

5. It is possible to bridge a gap and have complete restoration of the shaft from even a small sliding graft.

In brief, the technic followed for sliding tibial grafts was to use a bone saw to get the graft. Technically it is easier when the graft is at either end, but it is possible to graft the middle one third with a sliding graft. The incision was usually anteromedial off the crest. Skin grafts or scar excisions were carried out first. Occasionally in a doubtful case a scar was excised first as a test to see if infection would flare up. If no infection occurred, bone grafting was done as soon as the wound healed. Bad areas of skin were avoided, such as atrophic thin areas or adherent scars. The grafts were driven or wedged in. Metal was avoided. The casts were applied with the knee at 45 degrees flexion to prevent rotation and displacement for the first month. Antibiotics were routinely used before surgical intervention for one day and afterward until the temperature had been normal for two days. Wounds were closed with surgical gut for the periosteum and the subcutaneous tissues and with black silk or wire for the skin.

The averages for 25 consecutive cases in which sliding grafts were done are as follows:

Age of patients	27.4 years
Length of time from accident to final grafts	30.8 months
Length of continuous infection	15.8 months
Length of time from graft to walking with brace or without external support (This does not include 2 cases in which healing did not occur)	6.7 months

Among these 25 cases there were 13 in which there was infection of the wound; in 5 of these the infection subsided without treatment and was superficial.

There were 8 cases of severe infection. Amputation was performed in 1 of these, and in 1 union did not occur. In the remaining 6 patients the infection was eventually controlled either by surgical means or without treatment, and they are included among those who were ambulatory in an average of 6.7 months. One year after the last graft there had been no refractures or absorption of graft with resultant nonunion. Eleven patients were still wearing braces. All are now discharged from the army. The longest follow-up period was eighteen months.

Of the 25 patients, all but 2, or 92 per cent, were walking either with a brace or without support in an average of 6.7 months from the time of the bone graft.

SUMMARY

There is apparently an appallingly high incidence of postoperative infection (43.7 per cent in 85 cases) in patients with old war wounds, and unusual problems are presented. The principles for the final treatment of fractures with long term drainage are discussed. These include (1) not overloading tissues, (2) restoring function early with external aid, (3) avoiding the use of metal, (4) performing operation speedily with minimal trauma, (5) avoiding extensive disruption at the fracture site to remove scar tissue after Phemister's principles, and (6) waiting for a six month period after the fracture site is dry.

The results among 25 consecutive patients with a sliding graft in the tibia who were wounded an average of 30.8 months before grafting, with an average period of drainage of 15.8 months prior to operation, show that the graft was successful in 92 per cent, who were walking with or without braces in an average of 6.7 months from the time of surgical intervention.

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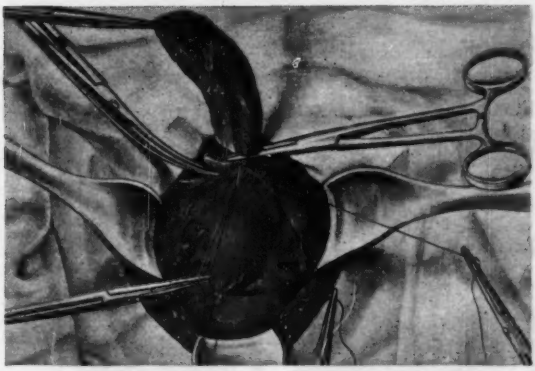

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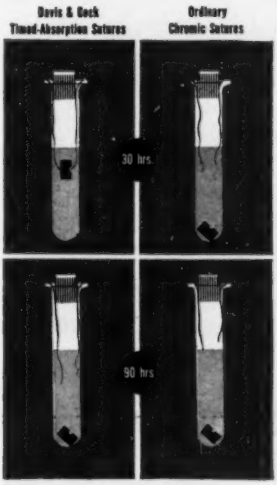

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